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AGRICULTURE

FOR SCHOOLS OF THE PACIFIC SLOPE

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AGRICULTURE

FOR SCHOOLS OF THE PACIFIC SLOPE

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PREFACE

AGRICULTURE is the most fundamental of all industries, the foundation and condition of civilized existence. The naturally growing fruits, roots, and other eatable products of forests and plains and the wild game and fishes of streams and seas are everywhere found to sustain only a roving and more or less savage population, few in numbers and failing to progress from century to century. Agriculture makes it possible for thousands to live comfortably where previously only a few individuals managed to obtain a scanty living without it; and, as agriculture is improved, still more people are able to live within a given area without warring over the means of existence. Mining and all the other important industries would quickly cease were agriculture to cease even for a short time, as they are sometimes obliged to do in India and elsewhere for lack of rain or irrigation water.

Improvement in agriculture, then, means the improvement of civilized existence, not alone of the farmer but of the world at large. And now that the increased means of communication and commercial intercourse has brought all the peoples of the earth

near together, it becomes doubly necessary that farmers should know how to carry on this work to the best advantage, and apply to it the same intelligence that other trades and professions bring to bear on theirs. In order to equip the farmers of the future, it is necessary to instruct the children of the country in agriculture, and the time has come when the subject must have a place in school teaching. This book has been written to meet the demands for a text-book which shall impress the pupils of the schools with the fact that the best intelligence is worthily bestowed upon the pursuit of agriculture. Throughout the work the authors have had in mind the needs of agriculture in both the arid and the humid parts of the West, especially in the states on the Pacific coast.

ACKNOWLEDGMENTS.—The authors have much pleasure in acknowledging the advice and helpful criticisms of Prof. C. W. Woodworth, Prof. R. E. Smith, Miss E. H. Smith, Prof. E. B. Babcock, Prof. E. W. Major, Mrs. Cady (née Chapman), and Prof. A. G. McAdie. They are under great obligation to those who have kindly furnished photographs as follows: to Prof. C. W. Woodworth for figures 50, 97–129, and 147; to Prof. R. E. Smith for figures 26, 131–134, 137–146, 148, and 149; to Mr. O. Butler for figure 135; to Prof. F. T. Bioletti for figures 45 and 136; to Mr. R. H. Forbes, Director of the Arizona Experiment Station, and to Mr. David Griffiths of the Bureau of Plant

Industry, for figures 18 *a* and 18 *b*; to Passenger Dept. S. P. Lines in Oregon for figure 173 *a*; to Mr. Paul Shoup for figures 7, 15, 25, 158, 159, 163, 165, 166, 168–172, 174, 177, 179; to the Phœnix Board of Trade for figure 16; to the U. S. Forestry Bureau for figures 18, 175, 176, and 178; to Prof. A. G. McAdie for figures 77 (photograph by Prof. J. E. Church), 78, 80 (photographs by Professor Ellerman), and 81; to Dr. B. T. Galloway for figures 19, 31, and 160; to the Walla Walla Commercial Club for figure 24; to the German Kali Works, New York, for figure 76 (from Wagner's Dungetafeln); to Mr. J. W. Sievers for figure 161; to the Utah Experiment Station for figures 162 and 164; to Mr. Colvig for figure 167; to the Sunset Magazine Home Seekers' Bureau, Portland, for figure 173; to the Yakima Commercial Club, Washington, for figure 15 *a*; to Mr. J. E. Peabody for figures 184–186; to C. P. Bailey & Sons for figure 199; to the De Laval Separator Co. for figure 198; to Prof. L. H. Bailey for permission to take from the Cyclopedias of Agriculture and of Horticulture, as well as from the Rural Science Series, figures 10, 30, 32, 33, 36, 37, 38, 40, 43, 46, 47, 49, 52–57, 182, 183, 187–197, and 200–209.

The portions of this book dealing with the physical and chemical aspects and the practice of Agriculture have been written by E. W. Hilgard; the biological and physiological portions, by W. J. V. Osterhout.

FOREWORD TO THE TEACHER

It should be specially understood and remembered by teachers that agriculture cannot be effectively taught if the pupils merely memorize the lessons and recite them. While the text should be placed in the hands of the pupils and its reading encouraged, it is vastly more important that their interest in the subject should be excited by demonstration and experiment before their eyes, and, so far as possible, that the experiments should be made by the pupils themselves whether in the schoolroom or in the garden. Short excursions to points in the neighborhood where agricultural operations are actually going on, or where the crops and implements used in their cultivation can be seen and handled, will be vastly more effective in exciting the children's interest and causing them to read in the book what they cannot actually see, than any amount of oral teaching. The pictures in the book, while designed to catch the pupils' eyes and attention, cannot replace the impression and full understanding conveyed by the objects themselves.

The first object of this book is to interest the pupils in the study of agriculture, and this should also be

the first object of the teacher. When once that is accomplished, farther progress and the voluntary and eager study of the details follow with little difficulty; especially in the open country, where the child is constantly surrounded by a multitude of objects that excite his curiosity.

As this book is intended for use in parts of the humid as well as in the entire arid region, it necessarily covers what might be considered an excessive extent of ground, owing to the great climatic differences existing within these regions. Teachers using it should understand that they are urged not to undertake to go through it from beginning to end with any one class, but to exercise judgment in selecting for use such portions as are adapted to the surroundings of each school, to the grade of pupils under instruction, and to the seasons. City schools will differ in this respect from country schools, and those of Arizona from those of Montana or Washington. It is hoped that the teachers in each of these regions can find in the text material of local interest to their pupils, and the opportunity of applying and illustrating in field, garden, or city markets the principles and objects that should be presented to their classes.

It should be emphasized that it is much better to teach a few subjects well, than to go over much ground hastily.

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AGRICULTURE FOR SCHOOLS OF THE PACIFIC SLOPE

CHAPTER I

WHAT PLANTS NEED (STUDY OF SEEDS)

PLANTS, like ourselves, have their needs. If they cannot satisfy their needs, they cannot grow. Some plants have much better ways of satisfying their needs than others. To watch them struggling to get what they need, and to see in how many different ways they go about it, is the most interesting part of plant study.

This is what we shall try to learn about. Whenever we look at a plant, we shall ask: What does it need? What does it do to meet its needs? How does every part work to help the whole? What enemies and difficulties does the plant have to overcome?

When we think over our own needs, we see that we can live only a little while without food. Without water we can hardly live more than a week; without air only a few minutes. Then, too, we must keep warm, and we need sunshine to keep us in the best health.

Do plants have the same needs that we have? Can a plant grow without food or water or warmth?

Can seeds grow without air? If we wish a seed to grow, we give it water. But if we put it under water, what happens? Fill two tumblers full of water. In one place some grains of wheat carefully on the surface of the water so that they float. Place some grains under water at the bottom of the other. Which grow best? Why?

Soak some wheat overnight. The next day place half a dozen of the moist grains in a bottle (which should hold eight ounces or more) and cork it tightly. Fill another bottle (of about the same size) full of the soaked wheat and cork it tightly. In which do they grow best? Why?

The seeds in the full bottle are like boys and girls shut up in a schoolroom without enough fresh air.

Where it is cold, seeds grow very little, for they need *warmth.* This you will see if you put them in a refrigerator or on ice. They will not keep on growing long in the dark, because they need *light.* And even with air, water, warmth, and light, seeds soon stop growing if they do not have *food.*

So we see that the needs of the plant are just the same as ours. The plant has difficulties in supplying its needs just as we have. Let us now think how we satisfy our own needs, and how the plant goes about it. First we will ask: —

How does the seed get water from the soil? When we plant seeds, we break the earth up fine and press it

firmly around the seeds to bring them in close touch with it. They can take up water wherever the seed cover touches the soil, for the seed cover has the power to absorb water. The covers of some seeds have this power to a great degree. The covers of other seeds (like buckeye or castor bean) seem at first sight to be almost waterproof, but they are able to take up water slowly. We sometimes crack or break hard seed covers (nuts, peach pits), or put them in a pan and rub them with sand, which serves the same purpose (small flower seeds). This lets the water in, and they sprout quickly. Acacia seeds are boiled two or three minutes to soften the covers and make them take up water.

FIG. 1. — The bean at the left has soaked in water only a few minutes. The next one has soaked a little longer. The one at the right has soaked longest. The wrinkling shows where the water begins to go in and how it spreads inside.

Some seeds take up water easily because their coverings seize upon it and fill themselves with it. These coverings may be spongy (nasturtium) or like mucilage (flax, quince, radish) or fibrous (outer husk of walnut). The chaff of grain and the pulpy covering of fruits and berries also act in this way. Put these and other seeds in water to see how they act.

Most seeds have openings by which the water enters and spreads in the seed (figures 1 and 2). If we place

seeds in hot water, air will come out of the openings, showing us just where these are. If we plant seeds so that the openings press against the soil, the seeds often sprout much more quickly than when the openings do not touch it (figure 3).

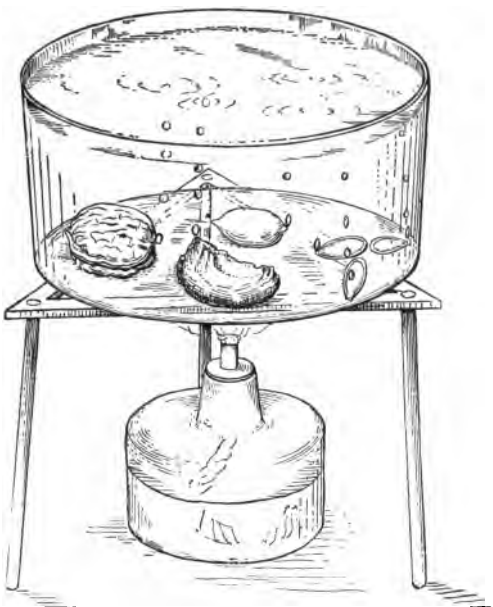

FIG. 2. — Seeds placed in hot water to find out where the openings are.

Good contact between seed and soil is very important. When we plant seeds, we first make a little furrow (not more than half an inch deep). We then place the seeds in the bottom of the furrow and cover them with fine earth. A good way to make the earth fine is by rubbing it lightly between the hands. Then we may pat it down and make it firm by pressing it with the foot.

Sometimes after planting the seeds we lay a narrow board over the furrow and walk along the board.

Then, removing the board, we sprinkle the furrow with water, which causes the earth to pack still more closely about the seeds. But we must not press the

FIG. 3. — The three rows of corn were planted at the same time. The grains in the front row were laid flat on the soil. Those in the next row had the pointed end upward. Those in the last row had the pointed end downward. All the grains were pushed just halfway down into the soil.

soil when it is wet, for we may thereby pack it so closely that air will not enter. Finally, we may place a shingle or some straw on the surface to keep the soil moist.

For planting seeds in the field we may use machines called drill planters, which place the seeds at just the right depth. The earth may be pressed down by small rollers attached to the planter, or by afterward going over the field with a roller.

How does the seed get air? When we water a plant which is growing in a pot, we see air bubbling up out of the soil as we pour on the water. If we pour on enough water, the air all comes out of the soil. It goes slowly back into the soil again as the water drains off and the soil dries.

The seed needs the air in the soil just as much as it needs the water. To supply the seed with plenty of air the gardener makes a loose, open soil into which air can easily enter. He does this by mixing in some leaf mold and sand. Then he gets good drainage by putting the earth in shallow boxes with holes bored in the bottoms, or in pots with a layer of gravel below the soil. If a crust forms on the top of the soil, he breaks it up with a hoe or rake to let in air.

How deep should seeds be planted? Fill a glass fruit jar or bottle with earth, placing seeds against the glass all the way to the bottom, so that you can see which germinate first. Does the result depend on how wet the soil is and on how closely it is packed?

How much force do seeds exert in swelling? Figure 4 shows one way to find out. Some dry beans are placed in an agateware cup in which holes are punched to let

in water. The cup is placed in a small pan of water. On top of the seeds we place a cup in which is a piece of wood. On top of this we place a three-cornered file or piece of iron for the iron bar to rest on. The iron bar is held at one end by the eyebolt *a*. At the other end we hang iron weights (hitching blocks or flatirons). A ruler is placed upright at *f* and a mark made where the iron bar crosses it. (In the figure a part of the outer cup is cut away to show the seeds.)

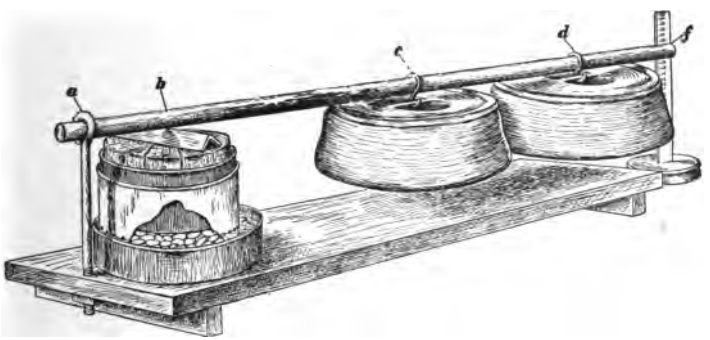

FIG. 4. — A way to test the swelling force of seeds.

As soon as the seeds begin to swell and the bar rises above the mark, put on more weights until it stops rising.

Before removing the weights tie a piece of wire or rope to the bar at the point *b* and see if by raising it you can lift as much weight as the seeds did. Perhaps if you fasten the wire to a stick which three or four persons can take hold of at once, you may be able all

together to lift as much as a small handful of beans has lifted.

The principle of the *lever*, which we use in this experiment, and in the ordinary steelyard scales, is a very important one which it is worth while to study further if you can.

The teacher may find out how much weight the seeds have raised by measuring the distance from *a* to the point on the bar from which the weight hangs, dividing this by the distance *ab*, and multiplying by the number of pounds in the weight. Do this for each weight separately, and add the numbers together. This will give the number of pounds raised by the seeds.

FIG. 5. — The swelling force of seeds. The bottle was filled with seeds and placed under water.

Fill a bottle full of dry beans; then pour in as much water as the bottle will hold, and place it *under* water in a pail and see the result next morning (figure 5).

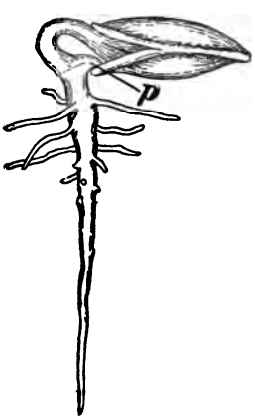

FIG. 6. — A squash seed, showing the "peg."

In most cases the seed germ comes out of the opening just

where the cover is weakest. Many seed coverings split easily (walnut, peach pit) in certain places. The squash has a curious peg which helps the seed to escape from the cover (*p*, figure 6).

What each part of the plant does. As soon as the stem and leaves get above ground they begin their work. The *leaves* absorb air and sunshine to make plant substance; the *stem* brings water to them from the root; the *root* searches for water and soil food underneath the earth.

CHAPTER II

HOW THE ROOT GETS FOOD FROM THE SOIL

How does the root get water? At first all plants lived in the sea, and there was no problem of water. But now plants grow even in the driest soil. From such soil a very large tree must take several barrels of water every day in order to live. How does it manage to get so much?

How is water held in dry soils? Not in the form of drops, as you can see by spreading out a little moist soil, or better, gravel, on paper. When first spread out, each little particle will glisten if the soil or gravel is moist enough. This is because there is a thin film of moisture on the surface of each particle. But this appearance does not last long, for the film of moisture quickly evaporates. *This thin film of water on the surface of each particle is all the water there is in such soil. There are no drops of water for the plant to drink up.* The particles are tiny water reservoirs which the plant must seek out and draw water from. This is the work of the root.

What the root does. To find moister soil the root should go down, and this it always does. Place it in

any position you like, and it will always bend so as to grow downward (this is due to gravity). Try the experiment with seeds lying on the top of moist soil. Keep them covered with a tumbler turned upside down, so that the roots do not dry up.

Where there is a main root growing straight down, it is called a *tap root,* and often this may go down many

FIG. 7. — Roots of an oak tree.

feet in search of moisture. Such plants as corn and grasses have no tap root; their roots spread out near the surface. *Such plants make early and rapid growth, but cannot stand drought like plants with taproots, nor get food from deep down in the soil.*

The small rootlets which spring from the side roots grow in all directions, searching every inch of soil for water and food.

Roots have the power to grow in the direction of moisture and sometimes find and fill up drains 300 feet from a tree. Many towns will not allow certain kinds of trees to stand within 100 feet of a sewer, because their roots find it and fill it up.

Roots grow faster and make more branches in moist soil than in dry soil.

The spread of the root is in general about the same as the spread of the branches. The fine ends of the roots ("feeding roots") are largely found where the drip of rain from the ends of the branches falls to the earth.

How deep do roots go? The roots of ordinary crops do not go down more than four feet in humid regions, but in arid regions they may go down twelve feet or more. For this reason an acre of soil in the arid region may be equal to much more than an acre in the humid region, since the roots reach and act on a much larger quantity of soil.

The roots of trees go so deep that grasses and many legumes may be grown in orchards without interfering with the tree roots.

Roots may have great length. The roots of a corn plant may have a total length of a quarter of a mile. The entire root system of a large squash vine was found to be over fifteen miles in length. These figures take no account of root hairs. In spite of such growth the root cannot reach enough particles to obtain enough

water for the plant. To do this is the special work of the root hairs.

How do root hairs reach the water? If we place radish seeds on the surface of moist soil and cover them

FIG. 8. — Root hairs of radish.

with a tumbler, they soon grow and we see their roots covered with fine white hairs looking like mold. These are the root hairs (figure 8). Each one is a long deli-

cate tube closed at the outer end and opening directly into the root at the other end. These little tubes or pipes reach the tiny water reservoirs and draw away the water from them. Since each soil particle is such a reservoir, the root hairs must force their way in among the particles and *come into close touch with them* in order to get at the very thin film of water which each particle holds on its surface. If you pull up the seeds, you will see that the particles are so firmly attached to the root hairs that they will be lifted up with the plant. The root hair fits itself closely to the shape of the soil particle, and may even grow around it so as partly to inclose it. The appearance of the root hair under the microscope at times reminds one of a hand clasping the soil particle firmly.

How do the root hairs absorb water? It would not be of much use for the root hairs to tap the reservoirs if they could not take away the water. The soil particle holds fast to the water with a good deal of force, which must be overcome by a stronger force before the water can be drawn away.

The root hairs take the water away from the particles in a very simple way. If we float half of a seed cover (*e.g.* of a squash seed) on water, the hollow side up, and sprinkle a little dry sugar on it (figure 9), the sugar will draw water through the cover. Sugar and other substances in the seed help to draw in water through the cover when the seed is placed in moist soil. In the

same way *sugar and other substances in the root hair draw in the water,* overcoming the force with which the soil particles hold fast to it. As fast as the water is taken away from a particle, more water flows to it from particles near by, and so these also give up their water to the root hairs.

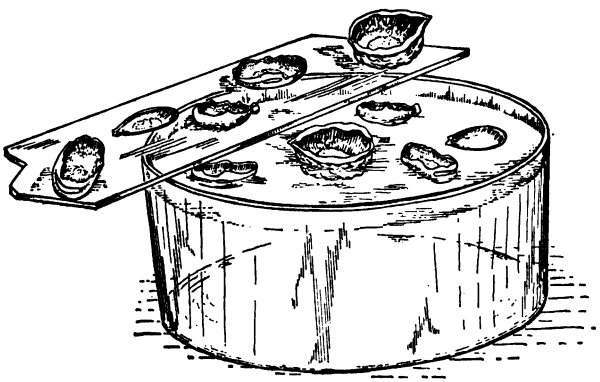

FIG. 9. — Seed covers floating on water. In each is placed three or four crystals of sugar, which draw the water through the cover and soon dissolve. This does not happen in the covers placed on the dry glass strip.

What are "feeding roots"? Root hairs are not found all over the root, but only at the ends of its finest branches (figure 10). Each root hair lives but a short time. It does not grow into a rootlet, but withers and falls away. New root hairs are continually formed at the ends of the fine roots. The root hairs increase the absorbing surface of these roots from seven to seventy times.

These fine roots are known as "feeding roots" be-

cause they do nearly all the work of taking up food and water. The thicker parts of the roots merely serve to carry the food and water upward to the stem and leaves.

How can we help the root in its work? *First, we must loosen the soil* so that the root can go down quickly and deeply into the soil. Although the root grows downward with great force (80 pounds or more to the square inch), and can penetrate hardpan or even such substances as hard sealing wax, it grows very slowly when the soil is too hard.

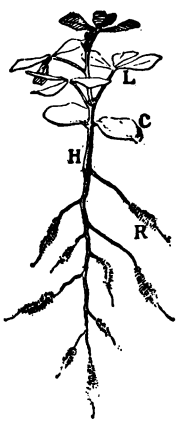

FIG. 10. — A young plant. (*r*) root hairs, (*c*) seed leaves, (*l*) true leaves.

Where there is hardpan beneath the soil we may have to dig holes through it, or blast it with giant powder so as to let the roots grow down through it.

Second, we must give the roots water. Sometimes when we irrigate or water plants we are apt to give them too much. We shall see how this is if we make an experiment.

How much water does the root need? We take several tumblers of the same size, place them in a row, and fill them with earth which has been made fine and well dried. We now add different amounts of water to the various glasses in order to see the effect on the wheat which we shall plant in them. Leave the first

tumbler quite dry, put a little water in the second, still more in the third, and so on, increasing the amount of water so that the earth in the last tumbler will be very wet. By looking at the earth in the tumbler in which the wheat grows best and rubbing it between the fingers you can get a fair idea of the appearance of soil which contains the right amount of water.

Third, we must give the roots air by breaking up the crust on the surface of the soil. The crust keeps out air and helps water to escape from the soil. If it is broken up, it makes a dry mulch which lets the air into the soil but keeps the water from escaping.

"Water your garden with a rake" simply means, break up the crust and keep the water from escaping from the soil into the air. This is the chief reason for tillage.

Roots need air to breathe. If they cannot get plenty of air, they may stop growing and finally die. This is why trees are often killed by flooding the soil with water, or even by covering it with clay or concrete in making roads or sidewalks.

When there is plenty of air in the soil, the roots can take up food much more rapidly.

If the soil is too wet, it must be drained by means of ditches. This lets in air.

In order to do these things properly, and so help the root in its work, we must know something about the soil itself, and this we will now study.

CHAPTER III

THE SOIL, HOW MADE, AND FROM WHAT

Soils are the earthy materials in which plants root, serving them as a foothold and source of moisture and food.

How are soils formed? Soils are made by the powdering and decay of rocks of all kinds. Each kind of rock makes a different kind of soil. These different soils are usually mixed together in various ways. Thus there are many more kinds of soils than there are of rocks.

ROCKS ARE BEING POWDERED IN DIFFERENT WAYS

First, by grinding. This may be done by the slow flow of the rivers of ice called glaciers. We see this going on in the high mountains (Oregon, Washington, British Columbia, and Alaska). In their slow movement these ice rivers produce all grades of rock powder, from finest flour to large cobbles and bowlders. Glaciers in times past also flowed down from the Sierra Nevada of California, and other glaciers covered the part of North America which lies north of the Ohio River; for there we find ground rock and cobbles and polished bowlders, scratched by movements of the ice.

Figure 11 shows a view of a glacier. To understand how ice may flow, we may support a long piece of ice, or an icicle, at both ends (leaving the middle unsupported), in freezing weather for several days. We will see it sagging down in the middle, and finally take the form of a U or a V.

FIG. 11. — A glacier or river of ice which is slowly flowing down from the great mass of ice and snow at the back of the picture.

Second, by weathering, by which is meant the action of heat, cold, air, and water upon the rocks. Heat expands and cold contracts rocks, as is the case with everything else. Thus the action of heat and cold makes crevices, at first minute, in the rock surface. Water and dust enter these, and by freezing, and also

by dissolving a little of the rock, enlarge these crevices to cracks, which then gradually cleave off particles of various sizes, and even bowlders. On mountains one can sometimes take up rock powder in handfuls from the surfaces of hard rocks.

Heat an iron bolt, for which you have a well-fitting nut, to dull redness; then try to put on the nut quickly. The nut will seem too small for the thread of the bolt until the latter cools or the nut is allowed to heat on the bolt.

If a blacksmith's shop is near, watch the putting on of a wheel tire. This is heated almost red-hot in a fire and then it drops over the wooden wheel easily. On cooling, it will fit the wheel so closely that it binds the wooden rim firmly together. In the common mercurial thermometer the mercury expands faster than the glass bulb, and so rises in the stem. This is true of all liquids and still more of gases. Observe how a white glass bottle when heated on the stove and then inverted in water will suck its neck full of water from the contraction of air, notwithstanding that the bottle also shrinks, but much less than the air.

Third, rocks are ground and powdered by streams of water, which may start from the ends of glaciers, from springs, from seepage water, or from the surface drainage of rains. The flowing water rubs and grinds the various sizes of rock fragments, sand, or powder against each other, forming rounded pebbles and cobbles on

the one hand, and on the other, the fine-grained valley or "alluvial" soils, prized for their fertility all over the world.

Break up a piece of clay or very soft rock; limestone will do. Put the pieces in a bottle of water, cork it, and then shake it hard for some time. Notice how the sharp edges become rounded. This is what happens to pieces of rock when ground together by running water.

FIG. 12. — Valley and stream.

Figure 12 shows a stream and valley. If we had to build a railroad straight across this valley, we should have to cut through the hills, and we could then see what sort of soil there is in them. Figure 12 *a* shows a cut of this sort made deep enough to show the soil in the valley as well as in the hills. The little mark right under the words "flood plains" stands for the river. On each side of it (under the word "bench") is fine soil brought by the river for a long distance

and dropped at this point because here the river flows more slowly. On the hillsides (under the words "colluvial soil") is soil which has slid down the hillside from above: it is

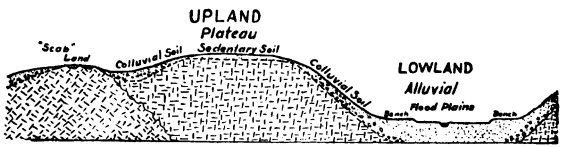

FIG. 12*a*. — The figure shows how a cut across the valley in figure 12 would look.

not as fine as that which the river brings, and does not give such good crops. On the top of the hill is soil which has not moved at all. It is formed just where it lies by the decay of the rock underneath.

Powdered rock and vegetation. But powdered rock is not yet soil; it requires the addition of vegetable matter, and still further weathering, to serve for plant growth.

Volcanoes often throw out finely powdered rock called volcanic ash. But for a number of years this ash can bear no vegetation. After several years, come, first, minute plants, called bacteria (page 250); then crust-like tree mosses (or lichens), such as grow on the bark of trees, begin to settle on the surface. The acids given off by the lichens eat into the surface of the stony particles, making them give up mineral plant food to the plants. These, when they decay, give to the soil some vegetable mold, or humus, which in turn enables higher plants, such as the true mosses and ferns, to

grow on the volcanic ash. These after a time give way to still higher plants such as stonecrops ("hen-and-chickens"), aloes, and such other plants as need but little soil or moisture. By the root action of these the soil is gradually increased and deepened, until shrubs and trees find foothold and flourish in the volcanic soil. The vine, olive, and fig are among the first crops that can be successfully grown on such soils.

In the mountains of the Pacific Coast many examples of this can be found. Volcanic-ash soils are common both in the Sierra Nevada and the Cascade Mountains, and in the Coast Ranges. Such soils are found in California near Colfax and Grass Valley, and southward on Calaveras and Kings rivers. We find them in the Coast Ranges in the Napa and Sonoma valleys, where wine cellars have been dug into volcanic ash which has hardened into a soft rock. They are also found southward in the petroleum region; much of the soft white rocks from under which the oil comes, are largely composed of volcanic ash, mixed with minute fossil shells. Similar deposits and soils are found on the flanks and in the valleys of the Cascade Mountains in Oregon and Washington, as on the Willamette, and on the plains eastward of Mounts Hood, Adams, and Tacoma, where the winds have carried the ashes.

Most of the soils now cultivated in the Hawaiian Islands are made from decayed black lava or from volcanic ash.

With solid rocks the process is the same, only they must decay at least on the surface, before the bacteria and lichens can settle on them. We see this in our

mountains. At the foot of granite ranges on the Pacific Slope, great sloping masses and beds of granite sand ("talus") may be seen (figure 13). These, when freshly formed and coarse, are barren for a number of years; while lower down, the land made from just such materials ground finer is very fruitful, as near Arcadia and on the Santa Anita ranch in Los Angeles County, California.

FIG. 13. — Sloping masses of rock at the base of cliffs. These slowly change into soil.

In the granite mountains of the Atlantic States, where much rain falls in summer, we sometimes find the rock softened (rotted) for many feet under the soil, so that the roots enter it freely to a depth of several feet. This is true also of the western (rainy) portions of Oregon and Washington, where the dense forest growth and heavy cover of moss prevent the soil from washing away, while the rapid decay of vegetable matter favors rock decay to the utmost.

Humus. We thus see that the decay of plant material, which in the end forms black humus or vegetable mold, is necessary in order to make good soil. The value of humus arises from its power to take up and

hold moisture, to loosen the soil, and to supply one of the most important elements of plant food; namely, *nitrogen.*

In countries where much rain falls, the fallen leaves and twigs, as well as the dead roots, supply the humus in the soil. Where rains are scanty, the soil humus comes mainly from the roots. For this reason the soils of dry climates contain little humus and are not usually dark. They are mostly whitish or gray (page 32). This is seen in the larger valleys and mesas of California, and in the plains of eastern Oregon and Washington, in contrast to the dark-colored soils of the lands west of the Cascade Mountains.

What is the outcome of rock weathering? The decay of the rock particles continues in the soils formed from them. This goes on most rapidly in soils containing much humus, because in its decay, humus gives off a good deal of the gas which also largely causes rock decay in the air. This is carbonic gas (carbon dioxid), the same gas that is produced in the burning of fuel, in the breathing of animals, and in many other ways. It is also the gas that causes the "fizzing" of soda water, and gives it the agreeable, slightly *acid* taste. This is because it forms with water an acid called *carbonic acid.* In most soils containing humus carbonic acid is always present, and helps to weather the powdered rock. It extracts from the rock powder the mineral food that plants require for their growth,

and makes it suitable ("available") for their use, so that it can be taken up by the roots. Other acids, having the same effects, also come from the decay of plants and humus in wet places, giving a brown color to the water. Such brown or coffee-colored waters are very common in swamps and bogs where the vine maple grows, in western Oregon and Washington, as well as in mountain and peat bogs everywhere.

Sand, silt, and clay. The weathering caused by these acids leaves behind, as the outcome of the decay of most rocks, *sand* of all grades down to silt or dust, and also *clay*.

Sand of various grades forms the bulk of most soils. The finest sands, whose separate grains can hardly be felt between the fingers, are called *silts*. Sands and most silts settle easily when stirred up in water.

Clay is often colored yellow, orange, or red by iron rust, which forms from the weathering of black or blue rock minerals.

How clay behaves. Pure *clay* does not settle in pure water for a long time; it may be made to settle quickly by stirring into the clay water a little quicklime or salt.

Method of separating soils. To show these facts, take a small handful of soil and knead it into a "mud pie" in the hand, then stir it in water to a creamy mush, and pour it slowly into a tall glass (or a student-lamp chimney closed at the small end) filled three quarters full of water. The coarse sand will settle to the bottom

at once, then successively the finer grades and silts which can be seen lying one above another, while the clay still remains afloat in the turbid (roily) water; and the last of it may not settle for days, weeks, or months, unless settled by lime or salt.

Or, prepare the soil in the same way, pour it into a large tumbler or glass jar, stir it up with water, and allow it to settle. After half an hour pour off the turbid clay water, stir the earth up again, let it settle, and pour off again, and so on until the water remains nearly clear. The sand and silt can then be stirred up again and the water poured off after four, two, one, half, and a quarter minute, pouring the water with the sediments into a separate tumbler each time. The different grades can then be seen each by itself.

Or, if you have pipe water under pressure, connect the faucet with a small pipe or glass tube and let a stream of water run into the sediment in the tumbler at different rates, catching the overflow in soup plates, in which the different grades of sand and silt can be best seen. Black specks of humus are seen in the finer grades, and sometimes the clay is quite dark with it.

If you have a piece of rubber tubing about six feet long, you can use it to siphon water from a bucket. By placing a step ladder on the table and raising the bucket from one step to another you can get different rates of flow.

Clay is peculiar. Dry clay touched by the tongue clings to it. When *wet* clay is touched by the finger, it clings to it in a lump. When *dry* clay is wetted, it swells, and when dried after wetting and working, it

shrinks, but keeps the shape into which it has been molded, as is seen in adobe bricks and unburnt earthenware. When heated red-hot, it becomes hard and cannot again be made pasty. These properties make it very important in soils.

Pure sands and silts are not sticky when wet, cannot be permanently molded by hand, and are not hardened by burning.

Natural clays, which can be found almost everywhere, are of many colors, — black, blue, green, yellow, red, gray, and white. Black clays often turn white in burning, while the other colors mostly turn to red or reddish, like burnt brick. It is the iron in the clay that causes these color-changes.

Sandy, loam, and clay soils. Sandy soils are loose, sometimes too much so, and easily crushed between the fingers. But when they contain some clay, they are firmer, the sand grains being held together by the clay. Such are the *loam* soils that farmers and gardeners generally prefer, because they are easily worked and are safest for crops. When soils contain too much clay or fine silt, they are difficult to cultivate. They are very sticky when wet, and when dry often become as hard as stone. Such soils are called *heavy*, or on the Pacific Coast, "adobe."

All cultivated soils, then, consist of *sands*, *silts*, *clay*, and *humus*. Some contain, besides, large amounts of iron rust, forming "red" lands.

Red lands are found in the California Foothills, on the Gila River in Arizona, the Laramie Plains in Wyoming, in Oregon, and Washington, where the black lava or basalt rocks underlie it, and in the states east of the Mississippi River. Red soils are also very abundant in the Hawaiian Islands.

Humid and arid regions. In the United States the country lying along the Mississippi River and eastward to the Atlantic coast has from thirty to sixty inches of rain every year, much of which falls during the summer. The same and even heavier rainfall occurs in Oregon and Washington west of the Cascade Mountains. This is enough to produce crops without irrigation when the rains come at the right times. This country we call the *humid region.*

West of the Rocky Mountains the rainfall is mostly less than twenty inches. There is but little rain in summer except in the higher mountains, and near their western slopes. What rain there is in summer frequently comes in heavy showers or cloudbursts, the water of which runs off without doing much good to crops. For this reason irrigation is necessary, or at least desirable, to make sure of good crops. These regions, where rain is scanty and falls mostly in winter, we call the *arid regions.* Just east of the Rocky Mountains lies the Great Plains Region, the western part of which, in the states of North and South Dakota, Nebraska, and Kansas, we call the *semiarid* (*half-arid*) *belt.*

Soil and subsoil. In the *humid* region (and in the low, wet lands of the arid region) farmers find an important practical difference between *soil* and *subsoil.* The soil proper is the *surface layer, made dark by humus.* Below this there is usually a yellowish *subsoil without humus,* and almost always containing more clay than the surface soil. The surface soil is seldom more than nine inches thick, and often less than six. As a rule it is only this surface soil that is cultivated, and in it the active feeding roots (see page 12) of plants are chiefly found. To bring up the "raw" subsoil would hurt the coming crop.

Arid soils. It is quite otherwise in the countries where there are no summer rains, and where irrigation is necessary (arid climates), as in most of California, also in Arizona, eastern Oregon and Washington, southern Idaho, Montana, and generally west of the Rocky Mountains. But little true clay is formed here in rock weathering; the soils are mostly powdery or sandy, and the scanty rains cannot wash clay from the surface down into the subsoil. Water and air, and with them the roots of plants, penetrate to much greater depth in arid than in humid climates; from a few feet to twenty and more. Very little humus is formed except from the decay of these roots, whereas in humid climates the leaf-fall adds greatly to it. Figure 14 shows these points.

Leaf-fall and humus. In the humid regions the leaves of most plants fall about the same time in the

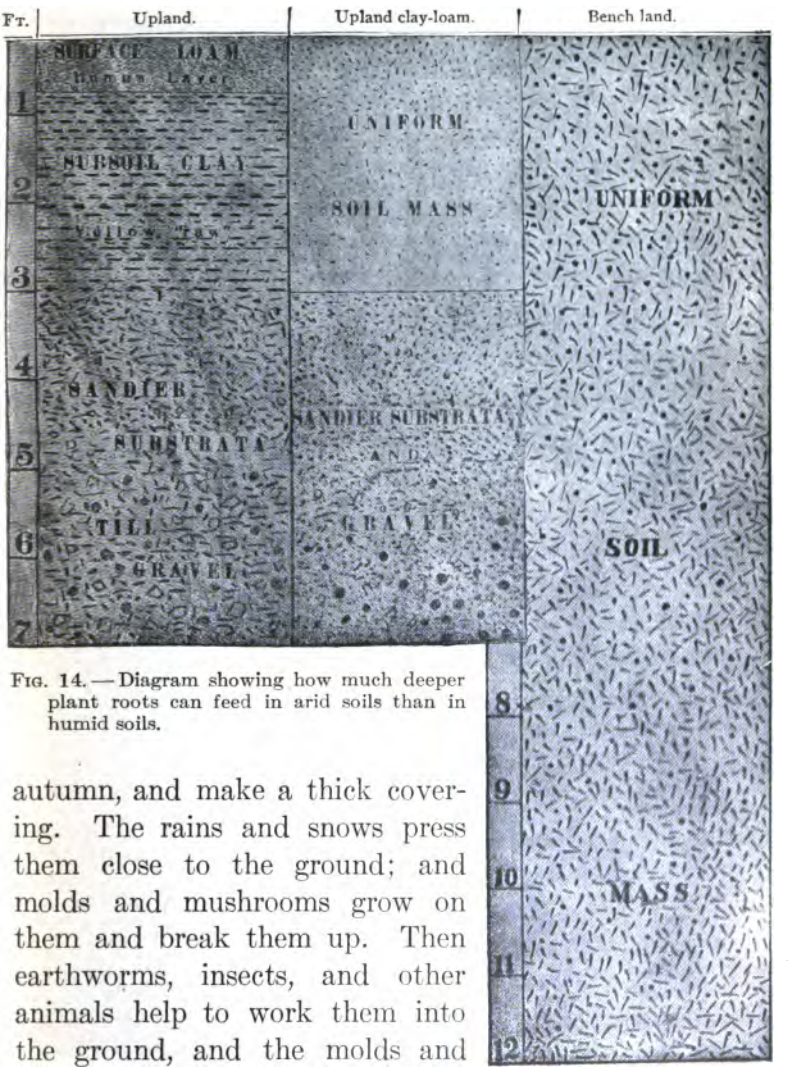

FIG. 14. — Diagram showing how much deeper plant roots can feed in arid soils than in humid soils.

autumn, and make a thick covering. The rains and snows press them close to the ground; and molds and mushrooms grow on them and break them up. Then earthworms, insects, and other animals help to work them into the ground, and the molds and

bacteria (page 250) make *leaf mold* and finally *humus* of them. Naturally this makes a dark surface soil.

In the arid states the leaves do not fall so regularly, and they are mostly smaller and fewer, and cannot make a thick cover on the ground. When they fall in open ground during the dry summer and autumn, they are blown about by the wind and torn to shreds, which are mostly dry-rotted and slowly burnt up by the sun before the rains come. So it often happens that even at the very surface of the ground there is very little humus, so that the soils look gray or white. It is only in low, moist places and hollows that enough leaves drift together to decay and form leaf mold. We also find leaf mold in the shade of the dense chaparal on the northern slopes of hills where the sun and wind do not reach.

Thus there is usually in California, and in most of the arid states lying west of the Rocky Mountains, little or no difference between soil and subsoil, outside of swamp and marsh lands. The farmer can plow as deeply as he pleases without bringing up raw, yellow subsoil unfit for the seed bed. He often has as many *feet* of soil as the Eastern farmer has *inches*, and (as will be seen later) his soils are as a rule much richer in food for the plant.

On all high mountains the rainfall (and snowfall) is greater than at their foot. Mountain climates are largely humid, as in the high portions of the Sierra Nevada, and of the

Cascade and Rocky Mountains in Oregon, Washington, and Idaho. Then, again, we find to seaward (westward) of the high ranges of the last two states, and also on the coast of California north of Cape Mendocino, a humid climate with summer rains. In northwestern Oregon and Washington these rains are very abundant; while just across the mountains to eastward (up to the Bitter Root and Blue Mountains) not a drop of rain may fall for five or six months. The soils, of course, on the opposite (humid and arid) sides of these mountains differ just as they do between the Atlantic states and California. The splendid crops of the Palouse country, and of the lands lying to southward in Oregon and in the Snake River Valley, are due to the great depth of soil and increased rainfall caused by the mountains to eastward.

CHAPTER IV

WHAT WATER DOES IN SOILS

How much water do plants need? Living plants contain from 60 to over 90 per cent of water or sap. The soil must be able to supply them, through the roots, with enough water to make up what they lose through the leaves (page 76). It has been found that to produce a wheat plant, over 300 times its weight (when dry) of water is needed; barley and oats need even more. A mustard plant needs about 900 pounds of water for every pound of the dry plant. An oak tree has been calculated to lose during the growing season some 500 pounds of water for each pound of dry leaves formed. A full-sized orange tree has been found to have about 40 pounds of leaves, weighed dry. Supposing the evaporation to be about the same as that of an evergreen oak, we find that orange trees evaporate about 2,000,000 tons of water per acre every year from 100 trees. This is equal to nine inches of rainfall.

All this water must be furnished by rain or by irrigation. Hence during the long rainless summers of the arid regions, irrigation is necessary to get good

crops. The native plants can do without irrigation because they for the most part either grow during or shortly after the rainy season. Some of them have their roots so deep in the soil as to find moisture where the drought and heat never reach. We should try to

FIG. 15. — Irrigation ditch. The water comes from the mountains which are seen in background.

make our cultivated plants do the same as far as possible, to save irrigation water and provide against its possible scarcity.

What are deserts? It used to be said that deserts are lands where nothing useful grows or can be grown. On old maps of the United States we see a large region

put down as the "Great American Desert." This included nearly all the country between the Rocky Mountains and the Sierra Nevada. That desert has now shrunk to small areas in Utah and Nevada, because it has been found that what used to be called desert

FIG. 15 *a*. — How water changes the barren sage country to orchards and fertile fields.

land is in most cases good land which does not get rain enough for the growth of crops. *The greater part of the desert soils, instead of being poor, need only water to give splendid crops.* Figure 15 *a* is a good example of how water changes the barren sage-brush country into orchards and fertile lands.

This is true even of the sandy surface of the Mojave and Colorado deserts in California, in some parts of which almost no rain falls. The lower part of the Colorado desert (the "Imperial" country) is being made by irrigation to give as good crops as the Land of Goshen in Egypt.

FIG. 16. — Building an irrigation dam in Arizona. When finished, the Roosevelt dam will be 284 feet high and able to hold water enough to cover 1,300,000 acres a foot deep.

It is only where the desert lands are stony or salty that they are sometimes impossible to cultivate. This happens in parts of Utah west of Great Salt Lake, and adjoining parts of Nevada, where the ground is covered with salty crusts too heavy to be washed out.

In most deserts, then, it is possible to get good crops if there is enough irrigation water and it is rightly handled.

What becomes of rain water? When rains fall on bare or hard ground, most of the water runs off without soaking in. This is called "run-off." On its way to the streams it often makes deep gullies in the surface of the land (figure 17). Except as it may be caught by reservoirs and streams used for irrigation, it is wasted by flowing into the sea.

FIG. 17. — As the result of faulty methods of cultivation the land is fast being cut up and washed away by the rains, and the farm-house must soon fall.

Enormous injury is often done in this way by the washing-away of the surface soil (and even subsoil) from the hill lands, and the burying of the flowing streams in the valleys. Figure 18 shows how in China the rich soil which is thus washed away into the streams is sometimes caught by building low mud walls in the river bed. The rich soil carried by the stream settles within these walls, and as soon as the floods are over, seed is planted and rich crops are harvested.

All this happens when the forest and shrubby growth is destroyed; or when the fields are plowed shallow and up-and-down-hill instead of "circling" around the

FIG. 18. — In some places so much rich soil is washed away by the rains that low walls are built in the river bed to catch it. On this good crops are raised.

slopes. When cattle are allowed to make hillside trails to water, the trails are afterwards often washed into gullies by the rains. Great areas of pasture have been ruined in this way in the arid states (notably in Arizona, New Mexico, and Montana). Figure 18 *a* shows Arizona pasture land in its natural ungrazed condition, while

FIG. 18 *a*. — Pasture land in Arizona in its natural condition.

figure 18 *b* shows similar land which has been ruined beyond repair. This was done by putting too many cattle on the land (overstocking) and allowing them to destroy the vegetation and make downhill trails to water. The heavy downpours of rain rushing down these trails first wash away and carry off the surface

soil, and soon enlarge into deep gullies the furrows which are formed at the start.

How is water stored in the soil? When the surface is loose and spongy, and the soil easily penetrated by water, as it is when covered by the natural growth of grass, shrubs, or trees, or when it is well cultivated,

FIG. 18 *b*. — This was once pasture land like that shown in figure 18 *a*. It has been ruined by washing and gullying because overstocked with cattle.

most of the rain water soaks in. It then sinks to such depths as will prevent its waste by run-off and evaporation at the surface. The soil mass thus acts as a great sponge or reservoir, storing the water for use during the rainless summer. It then supplies water to springs and streams and gives its moisture to field crops and

to orchard trees, whose roots reach to great depths in well-tilled soils.

The heavy rains called cloud-bursts sometimes penetrate only a fraction of an inch in compact soils, even though several inches of rain may fall.

To make the best use of the rain as it falls, the farmer must plow deeply in order to enable the roots to penetrate deeply. To help the storing of the rain water in his land, he must keep the surface loose and open, so that the rain may soak in quickly instead of running off and perhaps washing the soil away. In this way good crops may be grown even with only twelve to fifteen inches of rainfall. This is called " dry farming " (page 49).

Ground or bottom water: wells. The water soaks down into the land, and, if there is enough of it, it finally reaches a level where it meets the water already in the land. This level is called the bottom- or ground-water level, and it is to this level that we usually dig our wells to find enough water for household use and for watering stock.

Artesian wells. The dug wells just spoken of do not often supply water enough for irrigation. For this we have to bore wells to such depths as will reach the water which comes down underground from the mountains (or at least from higher ground). Such water rises in the bore hole, sometimes above the surface. In the last case we have artesian or flowing wells

(figure 19). Their water is usually purer than that of shallow wells, which are often within reach of drainage from houses and stables, thus becoming unhealthy, and causing typhoid fever.

FIG. 19. — **An artesian well. The water gushes up out of the earth and is carried off by the pipe at the left to irrigate the land.**

Ground water is sometimes found too near the surface to permit of growing crops. Permanent bottom water should not be nearer than five feet from the surface, for from that depth plants can get through their roots all the moisture they need without irrigation, and still not have the roots kept too wet or too near the surface. In the arid countries most trees are able to

get their water at depths of fifteen and even twenty and more feet; and alfalfa is sometimes found to have its main or " tap " root down to thirty and even fifty feet, reaching for bottom water. Alfalfa does not do well when bottom water is less than five feet below the surface.

Over-irrigation is hurtful. When by too much irrigation the ground-water level is made to rise too near the surface, trees and vines may die. Or at least they may not bear well, because their deep roots are killed by drowning. This may cause disease in the whole plant.

Where gravel beds lie under the soil, enormous amounts of water may be lost by draining into the springs and streams. The farmer must always watch what becomes of his irrigation water, by digging holes to find out how fast and how far it soaks down.

How is water lost into the air? Even after the water has soaked into the ground, a very large part of it may still be lost by evaporation under the hot sun and dry winds of summer; for the soil acts like a lamp wick, drawing up the moisture from below as it evaporates above. In this way it may waste the rain water of winter as much as does the actual run-off. Water evaporates fastest when the air is hot and dry and when there is much wind. More than a hundred inches in depth may evaporate from a water surface in the Colorado desert in a year. Twenty-five to thirty-five inches, however, is a more usual figure elsewhere. A wet soil

surface evaporates quite as much as a water surface. So, in the greater part of the arid states, it is easy to lose the entire rainfall of the year unless we make it penetrate the land by the means described above.

Wick action of soils. Soils differ greatly, both in the *rapidity* with which water rises in them by wick action, and in the *height* to which water finally rises in them (figure 20). In soils having much coarse sand, water will rise ten or fifteen inches in a few hours or days, and will then rise no farther however long you may leave it. Soils having much fine, powdery silt will draw up the water more slowly, but after one or two months, it will stop at a height of four or five feet. In some such soils water has been known to rise twelve feet in eighteen months. In clay soils water rises still more slowly, but may finally rise to forty or fifty inches.

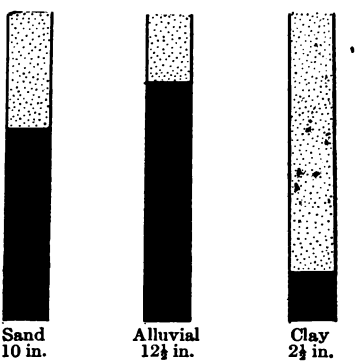

FIG. 20.—Three tubes filled with soil and placed with the lower end in water for two hours. The height to which the water rose is shown by the black part of each tube.

The picture (figure 21) shows how such trials are made. The glass tubes, or lamp chimneys, have a piece of muslin tied around their lower ends, which dip into water, which darkens the color of the soil as it rises.

How to prevent evaporation by mulching. To prevent evaporation, all the farmer has to do is what most good farmers in arid regions do already in their orchards. When the rains have stopped and the time has come to "lay by" crops for the summer, the land is cultivated and harrowed fine to a depth of five to eight inches, making a loose layer called the summer mulch, through which moisture will not rise to the surface any more. The effect of this is shown in figure 22.

FIG. 21. — Lamp chimneys filled with soil and placed in water to see how fast it will be drawn up by wick action.

In gardens we sometimes use straw, or other litter, as mulch, especially to cover for a time seeds that would otherwise be dried up by the hot sunshine.

FIG. 22. — New growth on two trees standing near together. The one had about it soil cultivated to form a mulch, the other did not. The longer branch and the larger fruit came from the cultivated tree.

The action of the soil mulch may be understood by what happens with a brick and sponge (figure 23). Soak a brick in water until no more bubbles rise from it, and then lay it on a dry sponge. Does the sponge take any water out of the brick? Now wet the sponge

FIG. 23. — Brick and sponge showing action of mulch. The sponge acts like a mulch because it cannot take water from the brick.

well and lay a dry brick on it and note how the brick sucks up the water and leaves the sponge almost dry.

The loose soil mulch acts like the dry sponge; the wet brick like the moist soil below, from which the loose mulch cannot draw the moisture to the surface. But if, instead of the mulch, a hard crust, from the beat-

ing of the rains, is allowed to remain on the soil surface, it then becomes like the brick; it will draw up the moisture from the soil below and waste it by evaporation into the air.

In the humid region the summer rains often form a crust each time it rains; this crust must then be broken up by cultivation to prevent evaporation. But there the roots of crops are mostly so near the surface that a thick summer mulch cannot safely be made without injuring them.

Dry farming. To keep up a good mulch during the dry season, and to keep the soil surface open so as to take up quickly any rains that may fall during the wet season, are the main points of what is called "dry farming" (figure 24). By this we mean farming without irrigation in regions where the rainfall does not exceed twelve or fourteen inches in a year. Good crops are thus grown where, as in a large part of the higher lands in the arid region, irrigation water is not to be had. Sometimes this is called the Campbell system of farming.

IRRIGATION

Of course, what is true of rain is also true of irrigation water. When land is flooded, the whole surface is wetted, so that however deeply it may penetrate, there must afterwards be much loss from evaporation, and crusts will form on the surface.

FIG. 24. — Dry farming in the state of Washington. Seed land that has lain fallow. Notice the mulch in the foreground.

Why we irrigate. We irrigate to make up for lack of rain, so that crops may get all the water they need at the right time. Irrigation on a large scale is most commonly done in the arid region, where there are few or no summer rains. Lawns, flowers, and vegetable gardens are watered more or less everywhere, so as to push their growth as much as possible.

How to irrigate. It seems most natural that we should imitate the rain when we want to make up for the lack of it, by sprinkling with a watering pot or hose sprinkler. But that can only be done on a small scale, and it is a very troublesome and wasteful way of using water. It is wasteful because, as a rule, nearly half of the water we sprinkle (particularly in the morning) evaporates into the air, and so is of no use to the plants.

Flooding. A common way to irrigate is to flood the fields or gardens from ditches. This is less troublesome at the moment, but cannot be done well unless the ground is nearly level. When the ground is uneven, as it mostly is, we have to level it first, and throw up little dams or dikes to hold the water long enough to soak the ground. We call this "check irrigation" (figure 25).

Furrow irrigation. But when we flood land, we still lose a great deal of water by evaporation. Therefore where water is scarce, we mostly irrigate in furrows (figure 26). That is, we draw furrows three to eight

FIG. 25. — Alfalfa field irrigated by flooding (check irrigation).

FIG. 26. — Furrow irrigation, showing deep furrows.

feet apart and let the water run through them until the land is soaked.

If we make these furrows deep enough — ten or twelve inches — and not too narrow, we can soak the land without any water coming to the surface at all, and so we may save quite half of the water we should use in sprinkling or flooding. But if we make the furrows shallow, — three or four inches only, — the water does not soak down well, and we wet a good part of the surface after all. Then we must wait until it dries, and so lose much of the water before we can close the furrows and loosen the surface. With furrows deep enough to prevent the water from rising to the surface by wick action, we can close them immediately after stopping the water, and leave the surface dry.

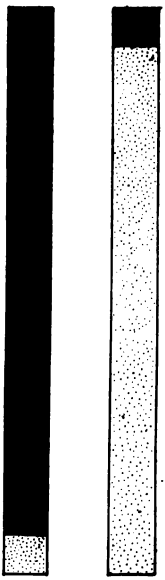

FIG. 27. — Diagram showing how far the water soaks down into silt and clay in 24 hours. The black part stands for the wetted soil, the dotted part for the unwetted part.

Penetration of water. But we must make sure that the irrigation water in the furrow really does soak down. The penetration of the water depends greatly on the kind of soil (figure 27). Sometimes, when the subsoil is hard, the water may be running in the furrow for days without penetrating a foot, and then we might as well not have irrigated. The diagram (figure 28) shows (at the

bottom) just such a case; and it also shows how much better the water penetrated from the deep furrows than from the shallow ones.

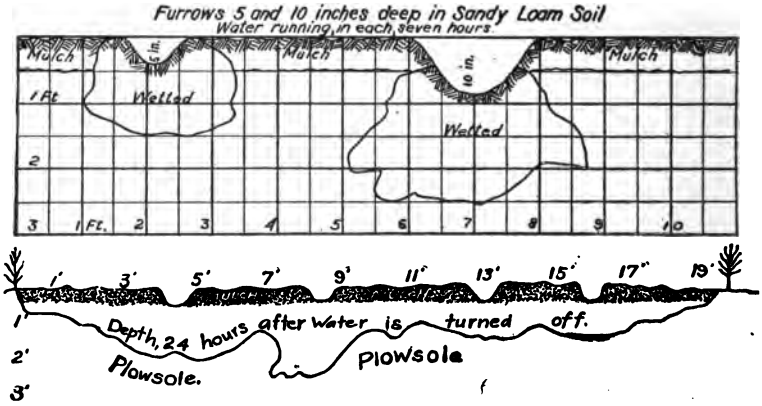

FIG. 28. — The upper diagram shows how much better the water goes into the soil from the broad furrow (at the right). The diagram at the bottom shows that the water will not go down into the hard subsoil (plowsole).

To find out what becomes of our irrigation water, we can dig down with a spade, or bore with a post-hole auger; or we may use the "soil probe," a square steel rod with a cross handle like a carpenter's auger at the top, and pointed at the lower end. The moist or wet soil is always darker-colored than the dry.

This probe should never be turned around, but only twisted a little way, back and forth. It then goes down easily when we bear upon it (figure 29), and, with a little practice, we can feel when the subsoil is hard, whether there is "hardpan" or sand, and also how far the water has soaked down.

Blasting hard subsoils or "hardpan." In some places there is a good deal of "hardpan." This is a kind of rock formed in the soil in sheets, at from three to six feet depth. Where trees are to be planted, it is sometimes blown to pieces by a charge of giant powder exploded at that depth before the tree hole is dug. The tree roots can then go down to their proper depths. The same can be done when there is close, hard clay subsoil at a few feet down. Digging the tree holes into such clay does no good. The holes are soon filled with water by rains, and the trees are likely to die, even if the holes have been filled with good soil.

FIG. 29. — Testing the soil by means of a "soil probe." This tells how far irrigation water has penetrated, and it also tells whether there is hardpan.

PLANT FOOD IN SOIL WATER

Water dissolves most things. When we boil down any natural water till its moisture has evaporated, we always find that something solid remains behind. This is best shown when the water is boiled in a bright silver spoon, in which a little white film or crust may then be seen. In a tea kettle that has been used for some time we find more or less of a stone-like crust that has gradually been left by the water. Sometimes, as in alkali or mineral waters, a residue is left which has a salt taste.

Water takes up (dissolves) nearly every substance that we see in daily life, including air. Even glass, and flint or quartz, are a little dissolved by water, and so of course is soil.

Put a teacupful of a loam soil into a funnel the neck of which has been stopped with a plug of cotton batting. Put some batting on top of the soil and then pour on, gently, enough distilled water (see page 58) to wet it, until a few drops come out at the beak of the funnel; these should be clear. Let it stand three or four hours or overnight. Then, while holding a bright tablespoon under the beak of the funnel, pour on more distilled water. Evaporate the clear water by heating slowly and note the crust or film that is left. Continue pouring water on the soil slowly, as before, draining away the water every few hours. After several days, evaporate another spoonful; there will be less crust or film than at first. But you may go on this way for a month, or a year, and still there will always be something left in the spoon when you evaporate the water passing through the soil, thus showing its "continuous solubility."

Much of this dissolving action of water is due to the gases it always contains, notably carbonic gas (the gas of soda water); and to oxygen, the most abundant gas in the air next to nitrogen, and the most important to animal life. Carbonic acid (formed when carbonic gas touches water) and oxygen, for instance, cause iron to rust under water, and the

water then gets an "inky" taste from dissolved iron. Copper, zinc, lead, and other metals rust in the same way. Well waters commonly contain in 10,000 parts 3 or more parts of solid matter. River waters contain about half as much.

Water dissolves plant food. Among the substances we find in water that has filtered through soil, the most abundant is usually *lime*, which is also one of the largest ingredients of most plant ashes. Soil water also contains some common salt, and if you boil a pint of water until only a few teaspoonfuls are left, you can taste the salt. There is also a little *potash*, the substance that forms the chief part of the lye from wood ashes. All natural water also carries a little *phosphoric acid*, which is a very important part of plant ashes, as well as of animal bones. There is always some carbonic and sulfuric acid, as well as some magnesia and iron, and often much silica, the substance which forms flint, quartz, and most sand. All these substances (with some others) are found in plant ashes, and, of course, have been taken up by the plant with the water it takes from the soil.

Since all plants take up these substances, we must find out whether they need them for their growth; and all experiments in trying to make plants grow without them have shown that, with the exception of silica, they are absolutely needed by plants. Hence we consider and call them *plant food*, together with *nitrogen*, which, as already stated, is mostly taken from humus by

the plant. It is dissolved in the soil water in the form of saltpeter. These and the carbon dioxide of the air make up the food needed by the plant.

Acids from the roots. Some plants have grown to seed in well water constantly renewed. So much water as this is rarely received by plants in our fields and gardens; but they help themselves by the acids which they give out from their roots, and which act upon the soil particles by dissolving plant food for the use of the roots.

Moisten some blue litmus paper and allow seeds to germinate on it to see if they turn it red. What does this show about acid excretions?

Soluble salts[1] in soils. Water dissolves from the soils of the humid regions about two hundred and fifty to three hundred pounds of mineral matter per acre. In getting these figures we suppose the soil to be only three feet deep. It never stops dissolving a little as long as the washing is continued (see page 56). In California, and the arid region generally, about ten times as much is easily dissolved at the first washing even in ordinary soils. There are more water-soluble matters (" salts ") in the arid soils, because the amount of rain is too small to wash the salts out of the soil as completely as in the

[1] The word "salts," as used in this book, means the mineral substances readily dissolved by water; such as, common salt, epsom salt, Glauber's salt, sal soda, saltpeter, and the like. In chemistry the word has a much wider meaning, which need not be explained here.

countries of abundant rainfall. We thus see that, also, more plant food remains in the arid soils than in those of the region of summer rains, where the plant food is washed into the streams and thence into the sea. Therefore the soils of the arid regions, when irrigated, nearly always give better crops than those of the humid countries. They contain, for example, about ten times more lime and three times more potash. Probably on this account the arid countries have been most anciently and continuously inhabited, as in the case of Egypt, the Holy Land, Assyria, Babylonia, and northern India.

CHAPTER V

TILLAGE AND CULTIVATION

By *tillage* (or preparation) is properly meant the loosening of the ground for seeding or planting; while *cultivation* is what is done while the crop is growing.

Wild plants do not need tillage or cultivation, because they themselves keep the ground loose by shading and covering it from beating rains; by their leaves which fall on it, and by their roots. In our bare fields, on the contrary, the surface of the soil is beaten and compacted by the rains so that a crust is formed. This will not let in water or air enough for growing plants unless the soil is loosened by tillage first, and then kept loose by cultivation.

Plows. The first plows used in historic times, *e.g.* in ancient Egypt, were simply forked sticks, of which the short end served to scratch the ground more or less deeply, while the longer end served as the tongue to which the man or draft animal was hitched. Such plows, or others differing but little from them, are still used in parts of China, India, Turkey, Russia, and even in parts of Europe. In light, naturally loose soils fair crops are made even with such poor tillage, but in heavy

clay soils they are of little use. Hence in India much fertile land of this kind was long left uncultivated (figures 30–33).

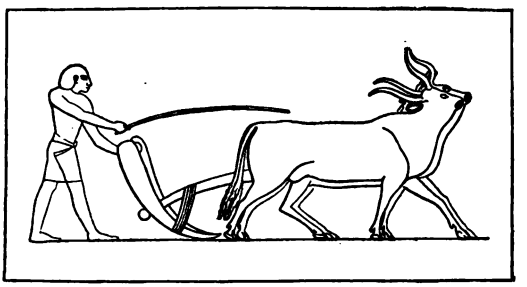

FIG. 30. — Ancient Egyptian plow.

In small gardens we use for tillage the spade, or spading fork, with which we dig up the ground. Afterwards, when we wish to make a nice seed bed, we smooth it with a rake. In large fields we use for tillage the turning plow instead of the spade, and the harrow or horse

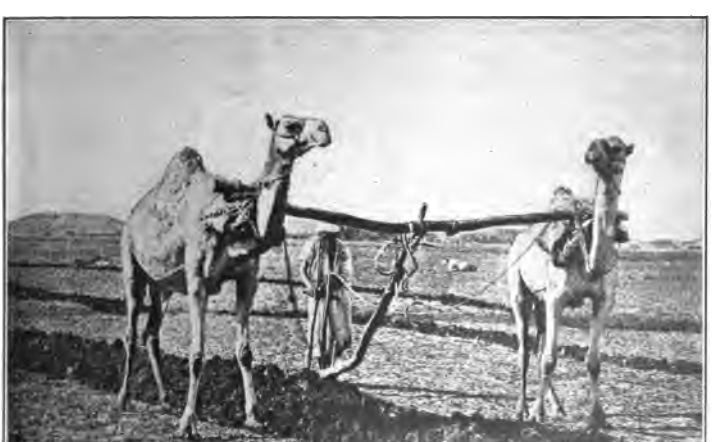

FIG. 31. — The method of plowing still used in Egypt.

FIG. 32. — A breast plow.

rake instead of the hand rake. For cultivation in gardens we use the hand hoe; in fields, the cultivator or horse hoe.

What these tools do. With the spade and turning plow we turn the surface layer of ground upside down and loosen it at the same time. This breaks up the crust which may have been formed on the surface by the rains, and lets in the air which is necessary for the healthy growth of plants.

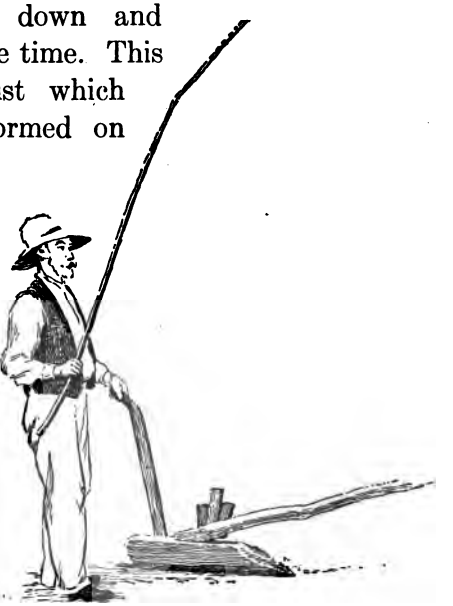

FIG. 33. — A plow still used in Chile.

Soil crumbs. Look at a soil that has been well tilled so as to form a good seed bed, and you will find that it consists of many

small crumbs. Each of these is composed of a number of soil particles, between which there are air spaces and each of which has a layer of moisture surrounding it. Such a soil crumb, about one hundred times the natural size, is shown in figure 34. The white spaces indicate the air bubbles, the dark spaces the water surrounding each grain. The water holds the grains together, and from these grains the root hairs (see page 13) get moisture and also plant food. When this water dries away, the crumb falls to pieces if the soil is very sandy. But if there is some clay, as in loams, the clay forms a kind of cement and holds the crumbs in shape, so that the air can still penetrate easily. When land is plowed with the turning plow in the right condition of moisture, the furrow slice (the portion that is turned over) will also fall in loose crumbs. The furrow slice will be higher than the unplowed land, and lie loosely. This is shown in figure 35, where *S* is the unplowed land and *fs* is the loose furrow slice.

FIG. 34. — A soil crumb greatly enlarged to show the particles.

This desirable crumb structure of the soil can, of course, be destroyed by tramping, especially when the land is wet; also by heavy, beating rains, and by

"black alkali." The compacting of the soil by the winter rains thus compels us to plow, or at least cultivate deeply, every year.

Crush some hard, dry soil by pounding, then put it in a tumbler and mark how high it reaches. Then dampen the soil by dropping on water gently while working it with your fingers. It will become loose and crumbly, and when put back into the tumbler it will be a finger's width or more above the first mark.

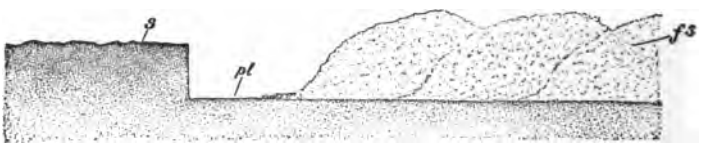

FIG. 35. — A diagram to show the effect of plowing.

How deep shall we plow and spade? That depends on the earth of the surface soil, — the layer containing humus or vegetable mold, — which has been fully weathered (see page 30). We have seen already that the thickness of this layer may vary greatly; from a few inches in the humid region, to several feet in the arid states, such as most of California, eastern Oregon and Washington, Idaho, Montana, Utah, etc. Therefore, in the Eastern states, the rule is that with the *turning plow* you should not plow deeper than from six to nine inches; as, if you go deeper, you turn up the raw, yellow subsoil, and spoil the seed bed. But in the arid region you may, as a rule, plow just as deep as

you like, because there is no "raw" subsoil except in low, moist ground. And this *deep plowing should be done, as a rule,* so as to enable the roots to go as deep as possible for moisture and plant food. But we should not plow to just the same depth every year, because then we may form a hard layer just below the plow

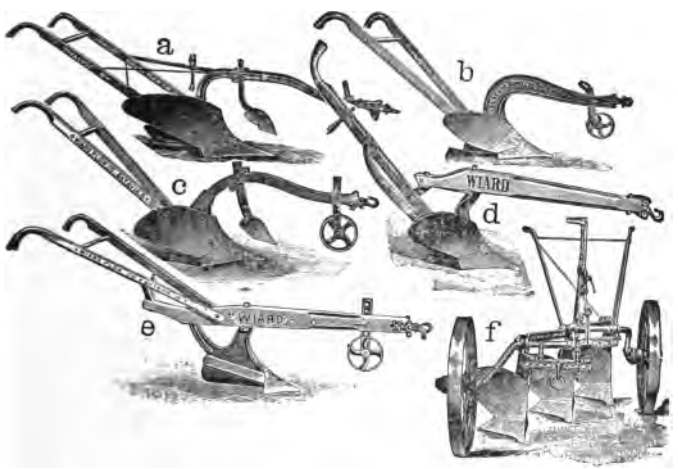

FIG. 36. — Various kinds of plows: *f* is a gang plow, turning three furrows at one time.

that will prevent the roots from going down. Such a hard layer formed by plowing is called a "plowsole" (see figures 28 and 35, *pl.*).

Instead of the turning plow we now frequently use the disk plow, which consists of two or more revolving sharp-edged steel disks set on an axis, which itself may be set either straight, or slanting so as to move the soil partly sideways and loosen it very thoroughly (see figure 37).

Subsoil plows. When a plowsole has been made by plowing to the same depth too often, or when there is naturally a hard, close subsoil, we may use a plow shaped somewhat like a chisel, which is made to follow the turning plow in the same furrow, but which merely loosens the subsoil without turning it up; so that it will be covered up the next time the turning plow passes. The water, air, and roots will then be able to penetrate into the subsoil and so give the plant a better chance for moisture and food. A great many different shapes have been given to these subsoil plows, and sometimes a "subsoiler" has been attached to the lower end (crossbar) of the turning plow.

FIG. 37. — Disk plow.

Shovel, scooter, or bull-tongue plows. Instead of the turning plowshare, these plows have merely a straight or slightly curved blade of varying widths pointing forward and shoving the earth to the two sides. In the arid region they are used chiefly in drawing light furrows for seeding, and in cultivation.

Cultivators. When crops grown in rows are weedy, or the surface is hard or crusted, we run between the rows the horse hoe or cultivator, a frame set with a number of little

plowshares of various shapes, from that of a turning plow to a scooter or bull-tongue, sometimes diamond-shaped. They are so set that the gaps left by the front teeth are filled in by those coming after, so as to stir up and loosen the entire space between the rows, breaking the surface crust and turning up the roots of the weeds. But as the cultivator cannot take out the weeds that grow in the row itself, we must often follow the horse hoe with the hand hoe to cut out the weeds in the "middles." Of these hoes there are also many different forms.

A very effective tool is the disk cultivator, consisting of one or two sets of steel disks mounted on revolving axles. These disk cultivators are sometimes used instead of plows, especially in orchards and vineyards, and for breaking up clods in plowed lands.

Harrows and rakes. When we have plowed, the ground is rough and could not well be seeded. We then smooth it and make the surface fine by means of a *harrow*, a frame set with round, flat, or square teeth which are so spaced as to rake the entire width of the frame. Sometimes these harrows are very large, or several are hitched together, so as to rake a broad strip of land at once. This is done in seeding land to wheat which is harrowed in.

On some soils, or when a disk or other harrow is not at hand, we may use for breaking the clods and making a good, smooth seed bed a drag, or plank harrow, which can easily be made on the farm itself, but does not last long unless made of hard wood.

A hand rake acts like a small harrow, and is used in the garden for the same purpose of raking the earth fine, and also for taking off weeds, straw, and trash.

Large rakes drawn by horses, and of many different kinds, are used for raking up hay into long piles ("windrows") and shocks.

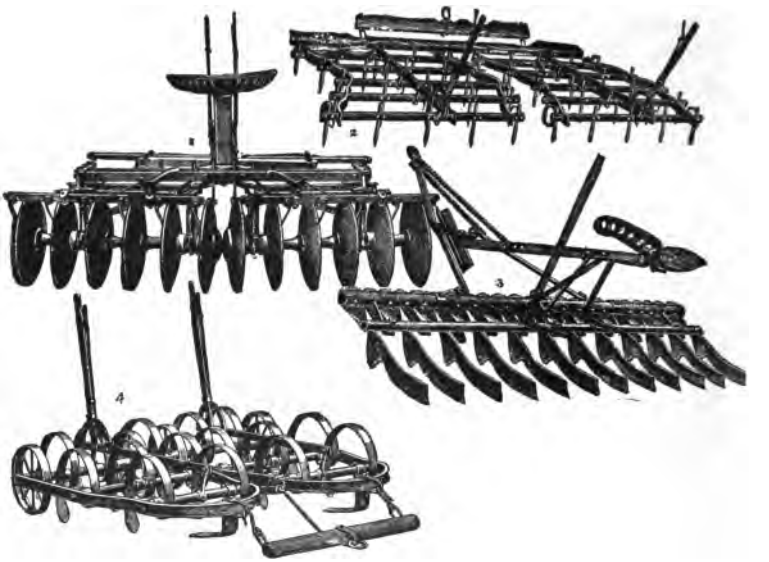

FIG. 38. — Several kinds of harrows: (1) disk, (2) spike tooth, (3) Acme, (4) spring tooth with side frames.

Rollers. When either of the tools described have left the ground too loose and open, especially after seeding, heavy rollers made of wood or iron are sometimes used to compact the surface a little, and press the moist ground around the seeds so that they may sprout better. Rollers are also used to break clods on tilled ground, and for that purpose are channeled, or made of square iron bars.

Earthworms. We should not forget that earthworms till the soil continually, except when the weather is too cold for them to work. They are constantly moving about in the soil, and help to keep it loose and open

by their burrowing. Darwin's book on earthworms contains many interesting facts about them. You will find it very entertaining to watch them and find out how they work.

SEED-SOWING

The sowing of seeds was formerly all done by hand. It is still so done in small gardens, and there are certain small seeds which cannot be sown so well in any other way, even in the field, when the sowing is to be done "broadcast," or uniformly all over the surface. This is true of many small flower seeds, and of the meadow grasses. The cereal grains (wheat, rye, barley, oats) were long sown broadcast by hand only, a process which required not a little skill to do it evenly. But for many years they have also been planted in drills by drilling machines, which in a number of states is thought to be best. In others, especially in California, broadcasting of grains is done by means of the "centrifugal" sowing machine. This throws out the seed from a rapidly revolving disk or solid wheel, through the center of which the grain passes, and is thrown out quite uniformly from the rim. This sower is placed on the rear end of a common farm wagon. The wagon is followed by several harrows hitched together so as to cover the width of the sowing done.

Small seeds such as clover and alfalfa are sown by

hand, and are often mixed with from four to ten times their bulk of sand or earth, as it is otherwise quite difficult for a sower to distribute so small a bulk of seed (say three or four gallons) evenly over the large surface to be covered.

Most large seeds, such as beans, corn, pumpkins, and the like, are sown in hills or drills only. For hill planting the "corn planter" is to some extent used.

Depth of planting and covering seeds. As has been shown (page 6), the depth to which the seeds should be put underground in order to germinate is very important. If we put the seed in too deep, we may never see it again. If we put it in too shallow, the ground may dry out before the seedling can send its roots into the soil; or the seed may not germinate at all. The best depth to which to sow or cover varies with different seeds and soils, and with the weather. The farmer cannot always foresee the weather to come, whether dry or wet, so he must use his judgment. Small seeds are frequently "brushed in" when sown broadcast, by means of a leafy branch or bush drawn over the surface. The grains are almost always harrowed in; in very sandy lands, and in the dry season in the arid region, they are sometimes put under with the cultivator or plow. Small garden seeds we sometimes cover with boards or shingles to keep the ground from drying out, until the seeds have sprouted, when the covers must be taken away. In sandy lands we often

use a roller to firm the earth around the seeds, so that they can take up moisture.

Some large seeds, like beans and pumpkins, are lifted out of the ground at the start by their growth. If the ground has had a hard crust formed on it by a beating rain, such seeds often cannot get through it to the surface, but coil up underneath and finally die. So it is well to protect the surface of a bean or pumpkin hill with mulch or manure to prevent the crusting. Some other large seeds, like the pea, maize, wheat, etc., come up with the sharp point of the sprout, leaving the seed behind, and do not mind the crust unless it is too thick and hard.

CHAPTER VI

HOW THE LEAF GETS FOOD FROM THE AIR

What is the work of the leaf? We often hear that the plant gets all its food from the soil. This is not so. Some of its food comes from the soil, but it gets most of its food from the air through the leaves. The first thing it does with the air food is to make starch from it by the aid of sunlight. And so we find starch in every active leaf. All the substance of the plant is made from the starch by the soil food which comes up from the roots. So the first work of the leaf is to make starch from the air food.

How the leaf takes up air food. The root must have as great a surface as it can to take up the little water the soil contains. The leaf must spread out as great a surface as it can to take up the little food the air contains. The leaves of a large tree may have several hundred square feet of leaf surface, but the real *absorbing surface* is *inside the leaf,* and is many times greater, just as the absorbing surface of our own lungs is greater than the outer surface of our bodies. The cells or chambers of which it is

made up are like tiny balloons with spaces between them in which air may pass freely. All of them together expose a great surface for absorbing air.

Why does the plant need so much leaf surface? Because there is so little food in the air (only one part in about two thousand parts of air). In a room twenty feet high, twenty feet wide, and forty feet long there is only enough air food to make about one pound of starch, and to make this in a day a leaf surface equal to that of the whole floor of the room is needed. This is only possible if the air of the room be stirred up the whole time and the room have walls of glass through which bright sunshine shines all day long.

Why does the leaf need sunshine to make food? From the sunlight we can get energy, or the power which makes anything move. By means of a burning glass placed in the sun we can make water boil and cause a tiny engine to go. If we knew how to use the energy of sunlight, we could run all our machinery by it. The leaves can and do use it in making food. We shall understand this better if we try a few experiments.

Is light needed for making starch? Pick some leaves (those of nasturtium or English ivy are good) near the close of a bright sunshiny day. Boil them fifteen minutes in water and cover them with alcohol (denatured alcohol or wood alcohol will serve). In the morning pour off the alcohol and cover them with

iodine solution.[1] If the leaves have much starch in them, they will turn dark in color. Now, by means of a box or piece of cloth or paper, cover up the plant from which the leaves were taken. Try to shut off the light from them as much as you can. After two or three days remove the box and test the leaves for starch as described above. If they contain no starch, it shows that what starch they had at the beginning has gone into the stem to help it to grow, and that they cannot make starch without sunlight.

Can the leaf make starch without air? Some of these leaves which have no starch in them may be used to answer this question. Place vaseline on the upper surface of some of the leaves, smearing it on thickly enough to keep out all the air. Cover other leaves on the lower surface only. After two or three days test for starch in the way given above.

If we find that covering the lower surface has more effect than covering the upper, we may be sure that it is because the air can enter the leaf more easily from the lower side.

Air enters the leaf and passes down into the stem so that both leaf and stem may breathe. Make a small hole in a cork (or, better, in a rubber stopper) and force the end of a leafy branch through it as shown in figure

[1] This can be made (by a druggist, if necessary) by dissolving potassium iodide in water (1 part to about 75 of water) and adding crystals of iodine until the color is dark brown.

39. Fill a bottle full of water and force the stopper as far down into it as you can. Placing a string or piece of fine wire between the cork and the glass aids this, as the water follows the string when it is drawn out. Take care that there is no air in the bottle. Now pull gently on the stopper, twisting it at the same time. Or hang up the bottle in sunlight as shown in the figure. The air which enters the leaves will be seen coming out of the end of the stem. Why? Magnolia and cherry laurel are good for this experiment. We may now ask the question: —

FIG. 39. — A branch fitted into a cork which stoppers a bottle of water. As the branch draws water out of the bottle air is drawn in through the leaves, and bubbles up from the end of the stem.

How does the air enter the leaf: *are there openings for this purpose?* Put some leaves in cold water and remove any air bubbles that cling to them by rubbing them under water. Bring some water to a boil, take it off the stove, and at once plunge the leaves into it. If there are openings, air will come out of them and show where they are. (Leaves of laurustinus, Christmas berry, cherry laurel, and geranium are good for this experiment.)

These openings are called *stomata* or breathing pores.

They can be opened and closed according to the needs of the plant.

When should the stomata be opened? If we put leaves into a fruit jar and close it tightly, it will not be long before we see drops of water inside the jar. The water comes from the leaves.

The leaf is always giving out water to the air. When water escapes from the leaf the soil food it contains is left behind in the leaf.

The more water the leaf gives off, the more soil food it gets. You will see how this is if you fill a tumbler half full of salt and then put in enough water to cover it. After a few minutes stir it and dip up a little of the clear water in a spoon. Let the spoon stand awhile. Now the water escapes from the spoon and goes off into the air, just as it does from the leaf. The salt will be left in the spoon just as the soil food is left in the leaf. We can see the salt and other soil food in the leaf if we burn it. The gray ash we get after burning is soil food left in the leaf when the water escaped from it.

By keeping the stomata open the plant can get more soil food, because then more water escapes and is replaced by water from the root.

When should the stomata be closed? On a hot day or in a strong wind, more water may escape from the leaves than the root can take up from the soil. What happens then? We all know how the plant then wilts

or droops and sometimes dies. To stop the escape of water as much as possible the plant closes the stomata. It opens them again when the danger is past.

Poisonous gases are sometimes used to kill insects on plants. This is done at night when the stomata are closed. Otherwise the gases would go through the stomata into the leaf and kill it also.

What happens if the stomata become stopped up? Smear vaseline on both sides of some leaves (without taking them off the plant). Spraying with oily liquids may have the same effect as the vaseline if not properly done (see page 412).

FIG. 40. — Blue gum showing leaves which, by hanging straight down, avoid excessive sunlight. Above, two leaves from a young tree; they spread out horizontally after the fashion of most plant leaves.

To prevent the stomata from being stopped up with water during rain, many leaves have coverings of wax or hair. Such leaves when under water look like silver, and the side on

which the stomata are found does not become wet (leaves of iris, blackberry, sheep sorrel, poplar, cabbage, and many others).

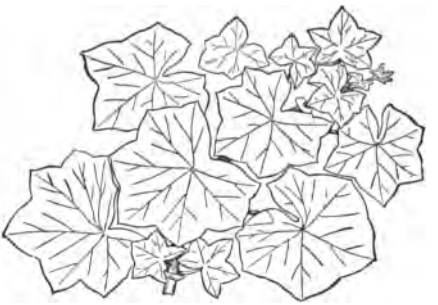

FIG. 41. — Branch of geranium.

These coverings of wax, varnish, or hairs also help to keep water from escaping from the leaf. Notice how well buds are protected from drying up by such coverings. The coverings are not, as generally supposed, for protection against cold.

Some leaves roll up on hot days (corn and grasses). This checks escape of water by making a smaller surface for the sun and air to act on.

Leaves that stand upright (iris) or hang down (eucalyptus or

FIG. 42. — Branch of chestnut.

blue gum, figure 40) get less sunshine and so lose less water. Desert plants expose only a little surface, having only a few small leaves or none at all.

FIG. 43. — The reach for light of a tree.

In winter most plants lose their leaves because the roots cannot take up water when it is cold; and so the plant must, as it were, take in sail and make its surface smaller.

What happens if the roots are chilled? Put a vigorous potted plant in a box. Then pack ice around the pot and fill the box with sawdust. Keep it in this

way for a week or more, putting in fresh ice when needed. What happens to the leaves? This shows us why cold irrigation water should be allowed to stand and become warm in the sun before being used.

Leaves avoid shading each other. Notice the leaves of English ivy and Japanese ivy. When a leaf is shaded it grows out toward the light, and so the arrangement shown in figures 41 and 42 is brought about.

Do leaves reach out toward the light? Notice plants which grow in front of a window. Do the leaves turn toward the light? If so, turn the plants halfway around; how long does it take for the leaves to turn back again? Study begonias, nasturtiums, and geraniums.

Do branches grow toward the light? Notice trees which are lighted mostly from one side, as trees at the edge of a grove or standing near a house (see figure 43).

CHAPTER VII

HOW THE PLANT USES THE FOOD IT MAKES

In order to make starch, soil food and air food must meet in the leaf, and the force or energy of the sunshine be used to join them together. Sap must come up from the root, and the food, after it is made, must go down into the stem again.

How does the soil food get to the leaf? We know that it goes up the stem in the water or sap which comes from the root. We can see how this is if we cut off a geranium or other plant, and put the cut end of the stem in red ink (or into water containing a little eosin, one of the Diamond dyes). After a few hours we may cut the stem into small pieces, and we then see that the colored water has gone up the stem in certain places only. You will see if you try to cut them that these places are really long strands of tough woody fiber. Under the microscope they look like bundles of tubes. In these tubes or pipes the water or sap goes up the stem.

When we cut the leaf and its stalk into small pieces, we see that the colored liquid has passed from the stem up into the stalk and veins of the leaf, and out into the

fine branches of the veins. And so the water reaches every part of the leaf.

We think that the leaves draw water up from the root in the same way that the root draws the water from the soil (see page 14).

In a tree, the water goes up the stem only in the young wood or sapwood. The outside of the stem is so covered with bark that very little water can escape. When a log seasons, the water escapes mostly through the ends. You see this when a green log is placed on the fire and water or steam is forced out by the heat. It comes out at the end even when the bark is off, because it can easily move lengthwise in the tubes which make up the wood, but not across these tubes (that is, across the grain).

The experiment in which colored water passes along the vein and into the cells of the leaf shows that only a part of the vein is needed to carry water. The other parts of the vein carry food (starch and protein) from the leaf down into the stem and root. Proteins are substances like white of egg, and are very important foods. The part of the vein in which they move is called the *bast*. In trees we find the bast just outside the wood. If we cut it away (thus girdling the stem), food cannot pass downward and the roots starve. Branches of grapevines are sometimes partly girdled so that the food may all go into the grapes, instead of leaving the branch and going down into the stem and roots.

What is the effect of girdling? Willow twigs as thick as a lead pencil and about eight inches long may be girdled half an inch above the lower end and placed in water so that the cut surfaces are covered by the water. Some of the twigs should not be girdled, but placed in water for comparison. Make deep and shallow girdles, some clear around and some only part way. In girdling, cut away the bark and bast clear to the wood.

If the food cannot pass the girdle the roots will come out just above it. But if it passes beyond it the roots will come out at the very bottom, as they do in the twigs which are not girdled.

Just outside the bast is the *green rind; this is where most of the starch and sugar pass down* from the leaves on the way to the roots and other places where they are needed.

The kinds of food. In seeds we find (1) starch, (2) fats and oils, (3) protein. All these may be easily known by simple tests.

What foods are found in the seeds familiar to you? You may test for starch by putting iodine solution (see page 74) on the broken or cut surfaces of well-soaked seeds.

You may test for fats and oils by scraping the seed with a knife, so as to make a fine powder. Put this on white paper; place the paper on a piece of tin and heat it (taking care not to let it scorch). The fat or oil will make a spot on the paper.

Test for proteins as follows: On a piece of boiled white of egg put a drop of nitric acid and then a few drops of ammonia water. The yellow color is a test for protein. Try the test on soaked seeds (especially peanut, beans, Brazil nut). Be careful in handling the acid; it burns skin and clothing.

What happens if some of the food is taken away from the seed? Remove the skin from some well-soaked beans and place them on moist sand or blotting paper, first taking one or both seed leaves from some of them. The dish in which they are placed may be covered with a piece of glass to keep the air moist.

All these foods in the seed are used by the growing plant or by animals which eat the seeds.

In what way is food used? The food is either (1) burned up, (2) built up into the plant, or (3) stored up. Much food is burned up. We must think of the plant as a machine which needs energy or power to run it. An engine gets its power from the coal or wood it burns, and the plant gets its energy from the food it burns. We all know that in cold weather we have to eat more to keep up the heat of our bodies, because we then burn up more food. Some small plants (bacteria) burn up more than their own weight of food every day. Figure 44 shows a frog, a burning candle, and some sprouting seeds placed in separate closed bottles or jars. After a time the air in all three jars is found to be changed so that nothing will burn in it. But if we

put green leaves into the jars and place them in sunlight, they change the air back again, so that a candle will burn in it again. The part of the air which is used up in burning or breathing, and which the green leaves in sunlight put back again, is called *oxygen.*

FIG. 44. — The burning candle, the sprouting seeds, and the frog use up the oxygen of the air so that nothing can burn in it.

When animals breathe they use up oxygen and give off carbon dioxide. Carbon dioxide is the *air food* which the green leaves take up and use in making starch. The green leaves give off oxygen in the sunlight, and this is taken up by animals in breathing.

What the plants give off is needed by animals: what the animals give off is needed by plants. So in making an aquarium we put in both animals and plants, and then both do well.

Plants digest their food just as animals do. When grain sprouts, some of the starch is changed to sugar. This also happens when it is digested by the animal. Taste some grains of wheat or barley which have sprouted. Are they much sweeter than grains which have merely swollen over night in water? This is because they have *digested* a part of their starch and changed it to sugar.

How is food used in building up the plant? All three kinds of food (fats, sugar, protein) are needed for building up the plant. They move about in the stem to the place where they are needed. When a potato begins to sprout, the starch moves up into the stem and down into the roots.

Where does growth take place? Only at the tip of root and stem (and at the tips of their branches) do we find growth in length. (Grasses also grow at the joints.)

How much of the tip grows? Place some peas on wet cloth in a dish and cover with glass. When the roots are an inch long, put ink marks on them (a quarter of an inch apart) by means of a splinter dipped in India ink. Use a tape measure as a guide. The marks will separate most where the growth is most rapid. Mark the tips of some stems in the same way.

What happens if the growing tip be injured? Remove the tips from some of the roots and stems, and see what happens.

How are the new parts formed in the bud? Get some heads of cabbage or Brussels sprouts. These are merely large buds. Cut them open and find the tiniest leaves as they are forming at the tip of the stem. Notice how new buds are formed just where the leaf is attached to the stem. Test these and other buds for food (see page 83). Certain animals live partly on buds in winter. Why do the buds have so much food in them?

How stems grow in thickness. We all know that just outside the wood of a tree there is a soft juicy layer which is protected by the bark which covers it. This is the place where growth in thickness takes place. It is called the *cambium*. It makes new wood and new bark all the time during the growing season.

When we cut off a limb, the cambium grows out and covers the cut surface (figure 45), so as to keep the wood from rotting. If we paint the cut surface with tar every little while, we can keep the wood sound until the cambium can cover it. Always cut off a limb close to the trunk; then the cambium will cover it much better than if a large stub is left sticking out from the trunk (figures 46 and 47).

The cambium makes scion and stock grow together in grafting. No matter what method of grafting be used, the cambium of the scion must be placed so that it presses against the cambium of the stock. There the two grow together and the graft is a success.

What protects the soft growing parts from drying up and from attacks of enemies? The cambium is protected by the bark. The tip of the stem is protected by the leaves which fold over it. In winter it is also

FIG. 45.—Cambium growing out to heal the wounds at the ends of grape cuttings.

protected by a sort of leaves called bud scales. They are covered with hairs, wax, and varnish to prevent drying up. The tip of the root is protected by a small cap called the root cap.

Remove the bud scales from the tip of the stem. Does it dry up?

What helps growth? "Good growing weather" is weather which is *warm* but *not too dry*. A great deal of water is taken up in growth. The soft growing parts are mostly water (more than nine parts in ten). When it is cold, water cannot be taken up fast enough for good growth (see page 79), nor can new substance be formed rapidly.

FIG. 46. — Improper cutting of a limb.

FIG. 47. — Proper cutting of a limb.

Land is sometimes offered for sale with a statement of the average temperature of the region. Such statements are wholly misleading unless the highest and lowest temperature is also given. A single day of

very high or very low temperature may ruin certain crops.

Does light help or hinder growth? Place two lots of seeds (or two potatoes) in different pots. Place one in strong light. Keep the other covered with a box. Keep the warmth and moisture as nearly as possible the same for both. Which lot grows faster (see figures 66 and 67)?

How food is stored up in the plant. All plants which live over winter store up food for future growth. Some store it in their roots (sugar beet, turnip, sweet potato), some in the part of the stem which is underground (potato), or in leaves underground (onions and other bulbs). Some store it above ground in leaves or stems. Here it is not so safe from animals and must often be protected by sharp spines, teeth, or a disagreeable taste. You may see this well illustrated in the cactus.

Trees store up a great deal of food in their trunks in winter. The wood and bark is sometimes ground up and mixed with flour in times of famine. The sugar of the sugar maple is such stored food.

Test the wood of oak, willow, hazel, or lilac for starch during the winter. Some trees (birch) store their food as fat. Test also various roots for food (see page 83).

CHAPTER VIII

HOW PLANTS ARE PROPAGATED

ALL the food that is stored up by the plant is for the purpose of propagation, by seeds or in other ways. Many plants go on storing up food for several years before they produce flowers (century plant, most trees). We find that flowers are often formed in the bud the year before they open, so that when the right time comes they grow very quickly. If we know just when the flower buds are formed, we may perhaps hope to control the matter by irrigation, putting on fertilizers, and similar means.

Cut open hyacinth bulbs, and see the small flowers already formed for next season's growth. Do the same to the large winter buds of horse-chestnut or buckeye. Use a hand lens if you cannot see the flowers with the naked eye.

FLOWER AND FRUIT

How are the young flowers protected? We find most flowers covered with a green covering called the *calyx*. If this be taken away, the flower dries up. It is made of leaf-like parts which are especially fitted for this

work, just as the bud scales are leaf-like parts fitted to protect the buds from drying up.

We have all seen the yellow dust of flowers. It is called *pollen.*

Of what use is the pollen? If we take away the pollen from the flower, it cannot make seed. Find a plant with large flowers which are making good seed. The large unopened flower buds (lily, passion flower, etc.) may be cut open and the *anthers* (or pollen cases, figure 48, which contain the pollen) taken out without injuring the outer parts of the flower. Now cover with a paper bag, tied tightly around the stalk (figure 49) to keep out pollen from other flowers which may be brought by insects or by the wind. Does the flower inside the bag set seed?

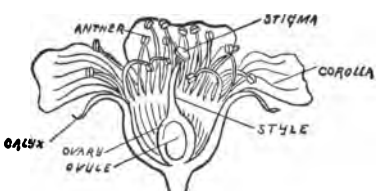

FIG. 48. — Cherry blossom cut open to show the parts of the flower.

It is not enough to have the pollen in the flower: it must be placed where it can get to the young seeds. These are in the seed case (or ovary) which is in the center of the flower (figure 48). At the top of the seed case is a sticky or hairy part, the *stigma* (sometimes on the end of a stalk called the style, figure 48), which holds fast any pollen which is placed on it. From here the pollen grows down to the young seeds (*ovules*). As soon as it reaches them, they begin to grow, and make perfect seed.

In some flowers the pollen can fall upon the stigma of the same flower and make good seed (self-pollination); in others it cannot, and the insects or the wind usually bring pollen from other flowers (cross-pollination).

FIG. 49. — A paper bag tied over a flower to keep out pollen.

What flowers can set seed without the help of insects or wind? Experiment on such plants as you can. Tie paper bags over the buds before they open, as shown in figure 49. If they set seed, we know that they do not need the aid of wind or insects; but with such aid they make better seed than without it, for the pollen from another flower makes better seed than pollen from the same flower.

Insects bring pollen to some flowers. We are told that insects are attracted by the bright colors of the petals, which are like sign-

boards advertising where honey is to be found. While this is true to a great extent, yet insects visit flowers such as those of grape, mignonette, and English ivy, which have no bright colors. In these cases the scent of the honey brings them. We know that they can smell honey long distances, while they can see but a few feet.

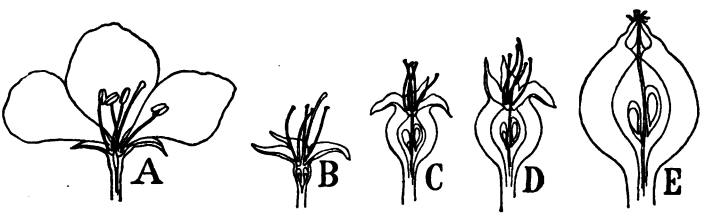

FIG. 50. — How an apple grows from the flower.

As they go from flower to flower, a good deal of pollen sticks to them, and in this way it is carried. Most flowers have some way of making sure that the insect places the pollen on the right spot, that is, on the stigma.

Wind brings pollen to some flowers. Plants which depend on the wind to bring pollen do not have bright flowers (grasses, oaks, hazels, poplars). The corn has all its pollen in the tassel, from which it is carried by the wind to the silk or long stigmas of the ear. The hop and hemp have seed-bearing flowers on one plant, and pollen on a different plant. The pollen-bearing must be planted about among the seed-bearing plants to supply pollen.

It sometimes happens that plants produce pollen which is not good. Then we must plant among them some plants with good pollen even if these plants be of a different variety. This happens with certain pears, plums, and grapes.

The pollen causes not only the seed, but the flesh around the seed, to grow. An apple which gets pollen only on one side sets seed and grows fleshy only on that side, and so makes a one-sided fruit.

In some figs the fruit grows and ripens without the action of pollen (Mission figs). In others (Smyrna figs) the pollen must be carried into the flowers by a tiny wasp (blastophaga) before the fruit will grow and ripen. The pollen is borne on a tree by itself (as in the hop), and this is called the "wild fig" or "capri fig." The figs of this tree are taken off and hung in the branches of the seed-bearing tree. Then the little wasp covered with pollen creeps out of the "wild figs" (which have only pollen), and into the seed-bearing figs, and these grow and make good fruit. Smyrna figs might have been grown many years sooner in California had this fact been known.

How pollen is protected. Pollen is easily spoiled by dew or rain, and nearly every flower has some way of keeping its pollen dry. Some flowers droop or close up at nightfall or when it is about to rain, and so foretell the weather (poor man's weatherglass, water lily, dandelion). Others always droop, or spread something

above the anthers to keep off rain. Some kinds of flowers fail to protect their pollen, and the crop of fruit is often ruined by rain at the time of bloom. Find out how the iris, sweet pea, linden, violet, and primrose keep the pollen dry. See whether by sprinkling water on them you can wet the pollen.

After the pollen has reached the young seeds and they have begun to grow, a fierce struggle for food begins. From the very first some take the food from the rest and grow faster. Often they kill the others, which shrivel up and in the ripe fruit are not seen at all. So out of many which start to grow, only a few may be left when the fruit is ripe, but these are large and of more real use than many small weak seeds would be.

Is there also a struggle among the fruits on the same tree? Do you find that some grow by taking food from others? Do all the grapes of a cluster grow to the same size? Do all the pears and apples on a tree grow large and become ripe?

When the grower "thins" the fruit, he thinks that the crop of fruit will gain enough in quality, size, weight, etc., to more than make up for the loss of the fruit he picks off. A certain weight of large fruit will sell for more than the same number of pounds of small fruit.

To get good fruit we must have plenty of food for its growth. In the early part of the season give the plants plenty of water and cultivate the soil; as the time of bearing draws near, give less water. Too much

water at this time makes leaves rather than fruit, and what fruit is made is without flavor. Trees are sometimes treated to prevent too much water reaching the fruit; the branches are cut or bent; the roots may be laid bare or pruned. If not carried too far, this makes more fruit and improves the quality.

Heat and dryness improve the flavor of fruit. Fruit grown in the mountains is therefore better as a rule than that grown in the valleys.

Ripening of fruit and seed. Many plants give up all the food they contain for the growth of the seeds and fruit, and die as soon as the seed is ripe. The stalks of grasses (hay) are sweet and full of food before the seed sets, but later give up their food to the seed and become tasteless. If they are cut before the seed is fully ripe, the seed goes on taking up food from the stalk, and ripens just as well. Grain cut in this way is not so apt to shed its seeds when it is carried about. But if it is " headed," the seeds should be allowed to ripen before it is cut.

During the ripening of the seed and fruit the food substances are changed. The sour or bitter taste of young fruit changes to a sweet, pleasant one, and the substances are formed which make the juice of the ripe fruit " jell " so easily. At the same time they become bright colored.

Does the change in color depend on the light? Pin a square or a letter cut out of tin foil or cork to an

unripe apple. Does it prevent the formation of color beneath it?

It is very important to control the ripening of fruit. Pears, as is well known, should be picked before they are fully ripe, and allowed to ripen in the dark, on shelves or in drawers. They are then not so gritty as those which ripen on the tree.

Fruit should always be kept in a cool place (in cold storage, if possible), and never exposed to the sun. The stalk should not be pulled off, since this leaves a wound which quickly softens and decays.

A decayed spot will cause decay wherever it touches another fruit. Hence, keep the fruits from touching each other as much as possible. It is best to wrap them in soft paper.

Fruit which takes some days to reach the market is sometimes picked green and allowed to ripen on the way. But it is better to pick it ripe, place it in cold storage for two or three days, and then send it in refrigerator cars.

Of what use to the plant is the bright color and pleasant taste of the fruit? There is no doubt that they attract birds which scatter the seeds far and wide. Some seeds and fruits cling to clothing or to animals (bur clover, tarweed) and are carried long distances. Some plants shoot their seeds into the air. Many seeds are carried long distances by the wind; these travel best of all. On the prairies the farmers build wire

fences to catch the " tumble weeds " (such as Russian thistle) which roll before the wind scattering their seeds. Those caught by the fences are burned.

Some seeds travel by water, and may even cross the ocean and spread the plant to new continents.

Seeds keep best in a cool, dry place. Some lose the power to grow in a short time, but most seeds live two or three years, and some can live a very long time.

How may seeds be tested? Seeds that we buy are often so old that they do not grow well. They may also be mixed with weed seeds. We may easily test them by putting them on some wet cloth or blotting paper in a soup plate, and covering them with another plate or piece of glass. Put them where it is warm enough to make them grow well. If eighty out of a hundred seeds grow, we may say that eighty is the percentage of germination. A simple test of this sort may save a good deal of money when buying large quantities of seed.

OTHER WAYS OF PROPAGATING

Why do we not always propagate plants by seeds? Some plants (such as apples and potatoes) do not give just the same sort of plant when propagated by seed, but do so when propagated by cuttings or by grafting. The seeds of an early apple may give late apples or winter apples, but scions or cuttings will produce a tree like the one they come from.

Many plants grow much quicker and better from cuttings or bulbs than from seeds.

How cuttings are made. Many plants will grow if you cut off a small piece of the stem and put it in water (wandering Jew or tradescantia, as shown in figure 51; willow, geranium, nasturtium). Other plants must be treated more carefully. If the stem is soft and green, we cut it just below a joint, leaving one or two leaves on it, and then bury it for half its length in moist sand. As it has no root it cannot take up water very fast, so we must shade it when the sun shines and keep it from losing water too fast. For the same reason we cut off the leaves except one or two.

FIG. 51. — A cutting of a wandering Jew in water.

If it is a woody stem, we cut it after the leaves have fallen off (in fall or spring) and keep the cuttings in a cool, damp place until the weather is warm enough for growth. Then we bury them for almost their full length in moist sand and keep them in a moist place. We take care to put them right side up. Then as we have seen (page 83), roots come out at the lower end and buds grow out at the upper.

Try the experiment of putting them in the sand upside down and see what happens.

The stems of strawberries strike root at the joints, and need only be cut off to make new plants. If we bend down the tip of a blackberry stem and cover it with earth, it strikes roots. This is called *layering* and is a good way to propagate blackberries, raspberries, and quinces. Many bulbs, if broken up, produce a plant from each scale or leaf of the bulb. If begonia leaves are cut into pieces and spread out on moist sand, each piece makes a new plant.

Many roots and underground stems (dock, morning-glory, bur clover) when cut produce a new plant from each piece. This is why some weeds are so hard to get rid of (see page 165).

How to transplant. The best way to grow many plants is to start them in boxes or plots and later transplant them. Unless one knows how to do this, the roots will be hurt so that the plant will die. But if you know how, you can make every plant grow.

First, make a hole in the earth larger than is needed to hold the roots. Line this with good earth made fine just as for sowing seeds (page 4). Take the pot in the left hand and turn it upside down, so that the dirt is held by the hand. Tap the pot with the right hand until the earth is loose and then lift it off. Now use both hands to hold the earth together while you set the plant in the hole. Pack good fine earth about the roots,

holding the plant with the left hand and pressing down the soil with the right. When it is all done, press down the earth with your foot and then pour on enough water to moisten the roots. At first the roots cannot take up water very fast, and so we must watch the plant and, if necessary, shade it from the sun.

If we wish to transplant a tree, we must wait until the leaves are off. Trees such as pines, which do not drop their leaves, should be transplanted in fall or winter, because then less water is escaping from their leaves.

It is a good plan to see that after as well as before transplanting the same side of the tree faces north.

Do not let a crust form on the soil about the plants, but break it up and form a mulch. This keeps the soil moist, so that the roots can do their work in the best way.

If a root is bruised or broken, cut it off with a sharp knife. If you leave it on the plant, it will decay and the decay may spread to the other roots, killing the plant.

The great secret of transplanting is not to hurt the roots, and not to let the plant get too dry while being transplanted or just afterward. A good way to plant trees without injuring the roots is to raise them in tin cans, and plant them can and all without disturbing the roots. The can quickly rusts and the roots make their way right through it. A cut in the form of a cross is sometimes made in the bottom and the flaps turned back when planting, in order to aid the roots in escaping.

How grafts are made. A cutting may be placed, not in the ground, but upon another plant. Then it is called a *scion*, and the plant on which it is placed is called the *stock*. We may in this way graft a peach scion on a peach, almond, or plum tree, for these trees are all very much alike. But if we try to graft it on a very different sort of tree, as, for example, a walnut, it will not grow. The scion gets its water and soil food from the stock, but this does not seem in most cases to change its usual way of growth.

FIG. 52. — Cleft graft.

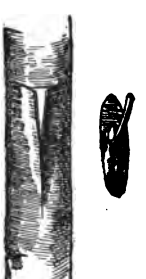

FIG. 53. — Shield budding.

FIG. 54. — Shield bud set.

On an almond tree we may have scions of peach, nectarine, plum, and apricot, yet each will produce its own kind of fruit just as if it were growing on its own roots.

We have already learned (page 87) that it is by means of the cambium that scion and stock grow together. The whole secret of grafting is to place the cambium of the

scion in contact with that of the stock, and keep them from moving or drying up until they can grow firmly together.

FIG. 55.—Whip graft.

If the stem is half an inch thick or more, we make what is called a cleft graft. A branch of the stock, an inch or more thick, is sawed off a little way from the trunk. Then a sharp chisel is driven into the end until a split is made to put in the scion (which should be about as thick as a lead pencil). The scion is placed as shown in figure 52. Two scions may be used if the branch is thick enough. The cambium of the scion must be placed in contact with that of the stock, as shown in the figure.

FIG. 56.—Grafting (inarching) the branches of two plants.

A veneer graft is shown in figure 57. The method of budding is shown in figures 53 and 54.

When we wish to graft a scion upon a stock of about

the same thickness, we cut them as shown in figures 55 and 57.

We tie them firmly together with grafting cloth, which is made by painting narrow strips of cloth with melted grafting wax.

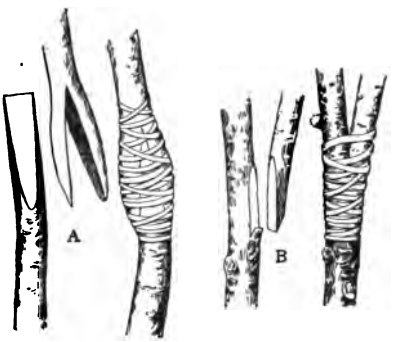

FIG. 57. — Saddle graft at *A*, veneer graft at *B*.

Grafting wax may be made by melting together two parts of beeswax, one of beef tallow, and four of rosin. Stir it well, then pour into water, and as soon as it cools work it like molasses candy until it becomes light yellow.

CHAPTER IX

HOW PLANTS ARE IMPROVED

OLD people nowadays remember the tomatoes of their childhood as small, tasteless fruits, too full of seeds and green partitions to be eaten. The splendid tomatoes of to-day have all been made by improving these poor sorts.

How are plants improved? We all know that good soil and good cultivation make better and larger fruit, but this improvement is lost as soon as the soil gets poor or the cultivation stops. In order to have real improvement we must get plants that produce better fruit without better soil or better cultivation.

Sometimes we find such a plant in our gardens. Growing in the same soil, side by side with other plants, it yet produces larger or better-tasting fruit. The first thing is to see whether it will come true to seed (that is, whether its seed will give plants like the parent). If so, we have a new variety and we give it a new name and put it on the market. We do not know how it came to be. We have not created it. We have simply found it, and our only care is to keep it and propagate it. We keep a sharp watch on its offspring to see whether some new and better plant will not

appear, for we know that a new variety is more apt to produce new things than an old variety.

If our new plant will not come true to seed, we propagate it by cuttings, or by grafting, or by some similar means, and it then usually comes true. We propagate new varieties of potatoes, apples, and many other plants in this way.

Sometimes it is only one bud or branch of a plant that produces something new (bud variation). An ordinary rose sometimes produces a single branch bearing moss roses. We propagate this branch by cuttings, and so get a variety of moss roses. But this happens so seldom that we cannot depend on it.

Improvement by selection. By selecting the best plants of corn every year (not merely the best ears), and saving their seed, we find that our crops of corn improve each year until a certain limit is reached. We may double our crops before we reach the limit. If we stop choosing the best ears each year, the quality of our corn is soon no better than it was at first.

Improvement by selection has this difficulty, that we must keep on selecting in order to keep our improvement, unless we should happen in the course of our selection to find a variety which comes true to seed or to some other method of propagation. In this case the finder usually says he has *made* a new variety, when the truth is that he has merely *found* one.

Professor de Vries has found certain kinds of even-

ing primroses, which make new kinds (mutations) without any assistance from man; and no doubt many other plants do so. This process is called *mutation.*

How can we make new kinds of plants? When we take away all the pollen from a flower before it has a chance to act on that flower, and then place upon the stigma of the flower pollen from another kind of plant, we make what is called a *cross;* and the seed produced by that flower gives a plant called a *hybrid.* This may be much better than either of the parents.

FIG. 58. — The improved beach plum is shown in the center. Its parents are shown on either side, an American plum at the left, and the beach plum at the right. Natural size.

An American plum was crossed by Mr. Burbank with a small worthless beach plum which grows wild along the seashore. The result of the cross is shown in figure 58. The fruit has the good qualities of both parents. It has a fine flavor without any trace of the bitter taste of the beach plum. And it has the hardiness of the beach plum, and will grow in all kinds of soils where the American plum could not grow. It will

FIG. 59. — A branch of the improved beach plum. The natural size of the fruit is shown in figure 58.

stand severe frost. And the way in which it produces may be judged from figure 59.

A cross between the plum and the apricot produced the plumcot, a new and delicious fruit.

FIG. 60. — The lower row shows the stoneless plum; the one in the middle has a normal seed without any stone; the one at the left has neither seed nor stone. The upper row shows the parents: at the left, *prunier sans noyau;* at the right, French prune.

A cross between the French prune and a small and worthless plum with a stone only partly covering the kernel gave the stoneless plum and prune shown in figure 60. In the center is no stone, but only a space filled with jelly containing a seed. It would be possible

FIG. 61. — Shasta daisy and one of its parents (the American field daisy). About one half the natural size.

to get rid of the seed, but Mr. Burbank believes it is better to keep it, as it gives flavor to the cooked plum.

By crossing the American daisy with the Japanese and European, Mr. Burbank obtained the Shasta daisy, which is not only much larger, as shown in figure 61, but has long stems and keeps a long time as a cut flower. A double variety as shown in figure 62 was made by continued selection.

FIG. 62. — Double Shasta daisy.

In all these cases of crossing only the best plants are saved. Out of a thousand perhaps only one or two are saved. The seeds of these are sown, and out of the plants which come from them only one or two of the very best are saved. This is kept up until the right kind of plant is obtained, or until it becomes certain that no good result is to be expected. In that case the plants are all destroyed and the work of years goes for nothing. New varieties of corn, wheat, vegetables, fruits, and flowers are being made all the time by these methods, and there is no end to the new forms which man may thus produce.

For a long time plant breeders worked in a " hit-and-miss " fashion, but now they are guided in their work by certain laws, particularly by the laws of Mendel. These are explained in two books, one by Professor Bailey, and one by Professor de Vries, each of which has the same title, " Plant-breeding."

CHAPTER X

HOW PLANTS ARE INFLUENCED BY THEIR SURROUNDINGS

We know that the needs of the plant are the same as ours; food, water, light, air, and warmth. If a green plant lacks any of these it dies. Too much of any one of these is as bad as too little. What the plant needs is the golden mean. Where the plant finds this it grows well. But there are many places where it must grow under unfavorable conditions. How the plant meets such conditions is worth studying.

Water. A potato contains sufficient water to sprout by itself, even when kept rather dry; if a potato which has just started to sprout is placed where it is not exposed to direct sunlight, it will continue to grow while lying on a dry table top and finally come to look like figure 63.

Its growth has been very slow (the ordinary potato plant of which a branch is shown in figure 64, grows a hundred times larger in the same length of time). Its branches are thick and clumsy. It bears no leaves, but their work is performed by the green rind of the stem and branches.

All this is just what we see in desert plants; in fact the whole appearance of this plant reminds us of a cactus.

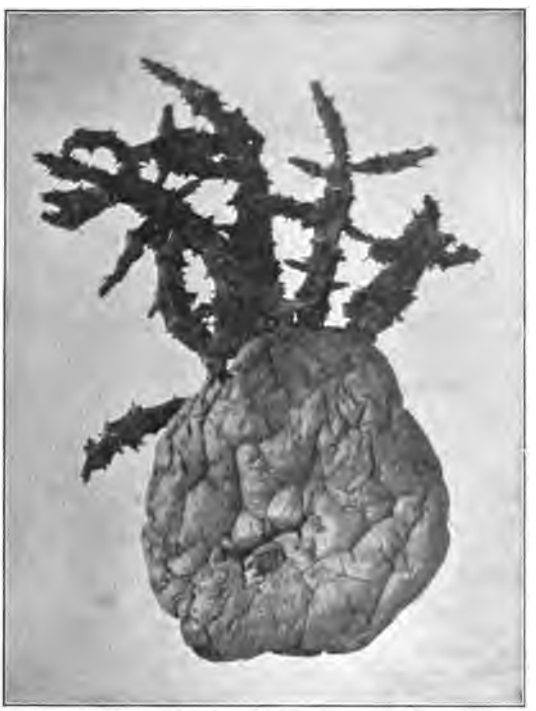

FIG. 63. — Potato which has been allowed to sprout and grow on a dry table top before a north window. It resembles a cactus.

On the other hand, we may, by growing a cactus in the dark, with plenty of moisture, cause the spines to grow out into leaflike organs. Figure 65 shows a sprout which has grown from a prickly pear under these

conditions. It will be noticed that the whole appearance is more like an ordinary plant than is the potato plant shown in figure 63. This sprout was obtained by taking a joint of prickly pear which was preparing to sprout, placing it in a pot of sand, and setting this inside a closed box to exclude the light. It was watered frequently, and in the course of about two months produced the sprout shown in the figure.

FIG. 64. — Branch of a potato grown under ordinary conditions.

Plants under dry conditions expose less surface to the air because the danger of drying up is so great. They make their leaves very small or get rid of them altogether. A cactus shows this very well. It has lost its leaves and has little exposed surface.

Plants get rid of their leaves in winter because they cannot get water enough during the cold weather. As soon as the roots become chilled they cannot absorb water. Cold irrigation water may chill the roots too much, and it should be run on slowly in shallow basins

so as to be warmed before it reaches the roots. Otherwise the fruit and even the leaves may drop off.

Nothing is more important than to give the plant all the water it needs. But of course the soil should not be kept too wet, for this drowns the roots, which need air as much as any other part of the plant.

FIG. 65. — Sprout of prickly pear grown in the dark, showing leaflike organs.

Other things being equal, the amount of a crop depends directly on the amount of water it gets. This we have learned by long experience and very careful experiments, and it agrees with what has already been said (on page 89) about growth.

Light. The effects of light are much like those of dryness and go with them; for in dry places the light is usually intense. Some leaves avoid intense light by growing in a vertical position (eucalyptus, figure 40, acacia). Young leaves are very sensitive to the light, and are protected in a variety of ways, usually by their vertical

position. Some leaves (sweet clover) take this position when the light is very strong in the middle of the day.

The trunks of trees may suffer from "sun scald," due to injury of the bark by the intense light and heat of the sun, or to the alternate thawing and freezing of

FIG. 66. — Young squash plants. Those at the left grew in the light; those at the right grew in the dark. All were planted at the same time.

the bark on the southwest side in late winter. The trouble may be prevented by shading the trunk with a screen of wire, boards, cornstalks, etc. Pruning often lets in too much light on the trunk, which suffers in consequence (this is especially noticeable in the weeping willow).

Very interesting results are obtained by growing plants in darkness. To do this out-of-doors it is only necessary to cover the plant with a section of stovepipe, a wooden box, or a barrel. Within doors the plant may be placed in a dark closet or box. Such plants (figures 66 and 67) have very long, slender stems (the nodes are far apart); they are pale in color, have little woody fiber, and are very weak.

FIG. 67. — The potato plant at the left grew in a moist, dark place; the one at the right in a very dry and sunny spot.

This fact is taken advantage of in bleaching asparagus, celery, and rhubarb for market. The celery is either "hilled" up or covered with gunny sacks, or the light is kept out by means of boards; the leafstalks are thus bleached and made tender and succulent. The "laying," or lodging of wheat, is due to excessive shading of the lower portion of the stalk, which results in too little production of woody fiber.

The leaves (in most plants) remain small and pale in color in the dark. Hairs and even prickles tend to disappear in darkness.

It is well known that intense light causes a greater intensity of coloring of fruits, flowers, and other colored parts of plants: this is especially noticeable in mountain regions. Compare the colors of flowers in shady woods with those of the sunlight of open meadows.

Light also affects the flowers and fruit. Many plants bloom little or not at all in poor light, while in strong light they bloom freely. This is seen in house plants grown at a north or northeast window, as compared with those grown at a south window. The effect is due partly to the fact that with better light the leaves produce more food for the growth of the flowers and fruit, partly to the direct action of the light (and heat) on the flowers and fruits. Notice plants that are partially shaded (as by a house or hedge), and note especially whether more blossoms appear on the side which is shaded or on the side which is toward the light.

You have probably noticed that many flowers grow or turn toward the light. This makes it easier for insects to find them.

Wind. Everyone is more or less familiar with the effects of wind on plants. Near the seacoast, or on mountains, or wherever trees are exposed daily to

strong wind, they show by their bent forms and curious shapes its strong influence (figure 68). The dying of the branches on the windward side (figure 68) is due to the drying effect on the wind, which may increase the loss of water as much as twenty times (see page 76). Even moist winds may have a drying effect.

FIG. 68. — The effect of wind on the growth of a tree.

It is interesting to observe that when for any reason the leaves and branches are developed principally on one side the stem grows thicker on that side. This may often be observed in vines climbing on walls.

The effect of wind in drying up the blossoms of fruit trees is well known. For this reason, and also because the winds are often cold and do considerable damage to trees laden with ice and snow, the use of wind-breaks is frequently necessary.

Food. We shall learn later on (pages 139–148) that the kind of mineral food the plant receives affects its growth and general appearance. Thus abundance of nitrogen causes a particularly strong, rank growth, and gives a deep green to the leaves, while phosphorus especially helps the production of flowers and fruit. It is a well-known fact that starving a plant makes it flower and fruit much earlier, though, usually, not so abundantly. A tree severely injured will sometimes bear a very abundant crop of small fruit before it dies.

Too much of any one substance in the soil may make it unfit for some plants, while others grow well in it. Thus, asparagus will stand so much salt that the weeds in an asparagus bed may be killed by sprinkling on salt, while the asparagus itself is not injured.

Soil that is too alkaline for ordinary crops may still raise stock beets and alfalfa; while land too alkaline for these crops will grow salt-bush, which makes good fodder.

Not only the chemical, but the physical nature of the soil and of the subsoil (whether hardpan or porous) is of importance. Find out what kind of land is considered best for the various crops with which you are familiar. Try also to learn to judge the land by the wild plants which grow on it. Plants show the character not only of the soil, but also of the climate.

Warmth. At the beginning of the chapter it was said that to give the plant too much of any of the things it needs is as bad as to give it too little. This is, perhaps,

more easily seen in the case of heat than in other cases. We all know that too much heat quickly kills both animals and plants. On the other hand, if they have too little, they stop growing and may die.

The less water the plant contains, the better it resists cold. This is well shown by greenhouse plants; too much water makes them very sensitive to heat and cold and to light as well; such plants are liable to "sun scald." Plants which have just been transplanted are said to be less sensitive to frost, since they contain less water. Frost does not injure buds in winter, when they are quite dry; but in spring, when they are full of sap, it kills them.

The way in which a frozen plant is thawed out is very important. Allow some potatoes to freeze (they may be easily frozen in a water-tight can, plunged into a mixture of pounded ice and salt, or set in an ordinary ice-cream freezer). Place some of the frozen potatoes in water chilled by ice (but free from salt), and let them stand until the water reaches room temperature. Place others at once in a warm place, so that they will thaw quickly. Note the difference in the outcome.

Plants are sometimes protected from frost by covering the plants with a mulch, or, in the case of trees and shrubs, by bending them down (the roots must be cut in such a way as to permit this) in the fall, and covering them with straw or brush.

Spraying or sprinkling with water at nightfall is a very good means of protection. This depends on the fact that moisture in the air prevents the loss of heat and the cooling of the trees and soil. It acts, so to speak, as a trap for the heat. Filling the air with dense smoke from smudges of tar, resin, or similar substances serves the same purpose.

Some kinds of plants stand far more cold than others (just as some kinds stand more water, light, or alkali than others). After a frost which kills most plants, it is often possible to find one or two which have survived, not because of a more sheltered position but by reason of their greater hardiness. By preserving the seed of such plants, and selecting seed from the hardiest plants year after year, hardy varieties may be obtained.

CHAPTER XI

POOR CROPS AND HOW TO GET BETTER ONES

Good crops are sometimes grown for a number of years, and then the crops become poor even when they have been well cultivated and given all the water they needed. If they are free from insect and fungous pests, the fault must lie in some condition in the soil itself. To get good crops again we must first know the cause of the trouble, and then remove it.

One of the commonest causes of poor crops is growing the same crop on the land year after year. The roots then take out the same substances from the soil in the same places every year. It is like using a grindstone in one place only, making a groove that spoils it for general use. The same crop should therefore never be planted more than twice in successive years. It is better to change the crop every year, selecting such as have very different kinds of roots (see pages 11, 287), and which take different proportions of food substances from the soil. This plan is called *rotation of crops.*

Rotation of crops. A grass or grain crop with *crown* roots should be followed next year by a root crop such as

beets or turnips. These have *tap* roots and feed largely on potash, while grains take up large amounts of phosphoric acid and nitrogen. Or grains may be followed by a legume crop, such as peas, beans, clover, or vetches, which also root deeply, and add nitrogen to the soil.

Rotation of crops will keep up and sometimes renew the crop production of lands in a surprising manner. It is growing wheat after wheat for years which has worn down so many rich lands in the United States, until wheat growing became unprofitable. The wheat must be replaced by clover, alfalfa, and root crops.

In practicing rotation it is usual to have a "money crop," readily sold for cash, such as wheat or cotton; then a manurial crop of some legume (clover, alfalfa, vetches) which at the same time may be a forage (cattle-feed) crop, or may be followed by one; then a "hoed crop" grown in drills or hills, like corn or beets, which clears the ground of weeds. Then we begin with the money crop again.

Fallow. There is sometimes one year of *fallow*, that is, a year when no crop is grown, the land being plowed and either left rough or harrowed. This "bare fallow" often results in a very much larger crop the next year, because of plant food being made soluble in the soil. But that plant food is very liable to be washed out of the land by rains. This plan is very wasteful of humus, and therefore of nitrogen, the most expensive of the fertilizing elements. We should therefore sow a "catch crop" of some rapidly growing plant, such as barley, oats, buckwheat, and others, which can be sown in summer and plowed under in autumn or early winter. We thus add greenmanuring to the benefit of the fallow with-

out loss to the land. In weedy land the weed crop sometimes answers the same purpose if plowed in before it goes to seed.

Plowing shallow, or to same depth always. Sometimes poor crops are caused by shallow plowing, which prevents the roots from getting deep enough into the soil for moisture and food. Then a great improvement can be made by deeper plowing. When this brings up the raw subsoil, as it may do in the humid region, it is called *subsoiling*. Turning up the subsoil must be done very gradually (not over an inch in one year) in the humid states; because plants do not grow well in such subsoils at first. In the arid region farmers may usually plow as deep as they please without hurting the crop to be sown. But even there, land should not be plowed to the same depth for several successive years, because then a hard subsoil layer, or hardpan (called plowsole), may be formed. Crops will then suffer for lack of moisture and food, not being able to go deep enough with their roots. Farmers should constantly watch their land so that this may not happen.

While in the humid region, and in the humid sections or places in the arid countries also, it will not do to turn up much of the subsoil at once with the turning plow, we can always deepen the soil by following the turning plow with a "subsoiler," which simply tears up the subsoil without bringing it to the surface, and so enables the roots to go deep for moisture.

Loss of humus. Again, in lands very well cultivated it may happen that because the crop was all taken off, and the weeds always kept down, the soil humus has all been burnt out by the sun and air. Then the land becomes difficult to cultivate, and crops become poor. The remedy will then be to grow green crops, preferably legumes, such as clover, alfalfa, peas, or vetches. When fully grown, plow them under and let them rot in the soil to form humus. This is called *greenmanuring*. When we have plenty of stable manure this will answer the same purpose even better.

Greenmanuring should always be done with legumes if possible, because we then not only put back into the soil what was taken from it in the growth of the crop, but also add to it the nitrogen such plants always take from the air by means of the root bacteria (see page 141 and figure 75, page 142). Such greenmanuring is in so far a real fertilization. Other plants, such as grasses (rye, barley, pasture grasses), give back to the soil only what they took from it (except the humus, which came mainly from the air).

Allowing weeds to grow. Sometimes the land has been allowed to become too full of weeds to give the crop a chance to grow well. This happens most commonly with crops that are not cultivated while growing, such as grain sown broadcast. If then the weeds go to seed before the grain is cut, the weed seeds will next season get the start of the grain and greatly hurt

the crop. Or, weeds may grow after the crop is taken off. (See the next chapter.) They may go to seed in fall or winter, and stock the ground so heavily that the weed seeds can sprout ahead of the crop and choke it. This is particularly true of the "little summer weeds" that some people think are not worth considering. In reality they usually seed more abundantly than the spring weeds.

Lack of drainage. While a sufficiency of water during the growing season is of the first importance, too much of it is often as bad as too little. Crop roots cannot do their work in water-soaked soils. Some plants grow in water, and many in swamps. But few *crop* plants can flourish with so much water in the soil, though low-lying lands are usually the richest in plant food and most desirable.

Too much water is best removed by draining; this is sometimes done by open ditches, and these, run so as to prevent the washing down of the soil by the run-off from rain, should be in all fields. But in level and low-lying land, water may stand in the soil for weeks in spring, keeping the land cold and preventing growth and cultivation. Ditches then carry off the water too slowly, and they are also in the way of cultivation.

By far the best way to remove the water is to lay *underdrains*, that is, pipes of burnt clay made in short lengths, and laid end to end at the bottom of ditches, which can then be filled up.

Such drains are particularly useful in clay or adobe lands, which are likely to remain wet longest. But the tile drains are useful not only to remove excess of water, but also to deepen the loose layer of soil and subsoil, so that roots can penetrate to greater depths and so find more moisture and plant food. Such a deep, loose layer down to the depth of the drains (three to five feet) also insures the better soaking-in of rain water, thus diminishing the run-off and surface washing and increasing the moisture supply in the land. It permits us to plow the land long before it would otherwise have been possible.

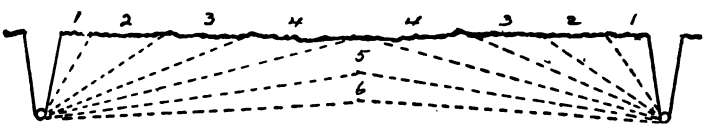

FIG. 69. — Diagram showing the effect of underdrains in loosening more and more soil year after year.

The cause of this loosening is that whenever a clay soil is wetted it swells, and then shrinks in drying. When this happens slowly, the surface of the ground rises and sinks. But over the underdrains the change is so quick that the soil clods are torn into small pieces or grains, which then let the water, air, and roots pass like so much sand. Gradually the effect extends sideways, until the whole space between the drains is loosened. This is shown in figure 69.

How water gets into the underdrains. People sometimes ask how water gets into the drains through the close joints between the tiles. This can easily be seen by looking into the ends of drains during a wet time. We can then see the water spurting in at the joints. The danger is not that the water will not get into the drains, but that sand and earth may, and so clog the pipes, compelling us to dig them up and clean them.

So underdrainage is a remedy not only for excess of water, but also for injury to the crop by drought. It helps to make crops early and safe, and enables them to get more moisture and plant food. It is expensive, but increases the crop-producing power and value of the land very greatly. It makes the success of crops much more certain and regular.

Some soils are naturally underdrained. This happens when there is sand or gravel underlying them at from three to five feet, or when the soil and subsoil are both sandy. It is then not necessary to lay underdrains. In the humid states sandy soils are usually poor; in the arid region the sandy lands are apt to be quite as rich as the clay soils (see page 34) and are therefore much valued for cultivation, being easy to work at all times.

ALKALI SOILS

A common cause of poor crops in the arid regions are the soils which, because of a light rainfall, have retained in them most or all of the soluble salts which have been formed from the weathering of the rocks (see page 58). This is the case in many areas west of the Rocky Mountains, and in the "semi-arid" belt, lying along their eastern foot. In California, Nevada, Arizona, New Mexico, and northward nearly to British Columbia, such "alkali lands" are found more or less.

FIG. 70. — Alkali lands in San Joaquin Valley, California. The white spots have a salty crust.

How to know alkali soils. Alkali soils are usually known by the fact that they have a white (sometimes brown or black) crust of salts on the surface in the dry season, or when sunny weather comes after rains. This is because the soil water, evaporating at the surface, brings the salts up with it.

Sometimes this crust tastes strongly of common salt, but mostly it is also bitter (the taste of Glauber's and Epsom salts), and when dark-colored it tastes of salsoda also. In the latter case farmers speak of "black alkali," otherwise of "white alkali." And they know that black alkali makes it more difficult to grow crops than when the alkali is white; that is, when it consists mainly of common salt and Glauber's salt, with little or no salsoda or carbonate of soda.

The three salts mentioned are useless or injurious to vegetation; the land would be better without them. But at the same time with these useless substances, the scarcity of rain has left in the alkali soils also the whole of the plant food set free by the weathering. When reclaimed by washing out the noxious salts, alkali soils are therefore highly and lastingly productive.

Getting the alkali out of soils. To get the alkali out of soils we have only to do what nature does in regions of abundant rains; wash it through the soils into the streams, or underground drainage.

When the soils are very sandy, flooding with irrigation water quickly does this; but usually it would take a great deal of time, especially in black alkali lands, where water soaks down very slowly. We may then underdrain the land

by laying drain-tiles in narrow ditches, cut three or four feet deep, from which the alkali-charged water will flow easily when the land is flooded. Or else, as this is quite expensive, we may leave the water on the land long enough to carry the alkali down to three or four feet, then sow or plant the

FIG. 71. — The growth of wheat improves from year to year as the alkali land is being reclaimed by proper treatment; at the left after one year of treatment; at the right after four years of treatment.

FIG. 72.—The orange tree at the left was irrigated with artesian water; the one at the right with alkali water.

crop, with which the alkali cannot then interfere until the roots get strong and far down, and are not so easily hurt. But when we have thus washed the alkali down in the land,

FIG. 73. — Salt grass, which is found in strongly alkaline land.

we must keep the surface well cultivated to prevent its being brought up again by wick action and evaporation. That is, we must keep a soil mulch on the surface, and irrigate in deep furrows. See Chapter IV.

How does alkali rise in soils? Place a little dry eosin (a Diamond dye) in the bottom of a tumbler; fill with soil and keep it moist. This will illustrate how alkali rises in soils which are irrigated. You can also use salt instead.

How can alkali soils be reclaimed? Tie a cloth over the bottom of the tumbler, crack the bottom with a hammer, and allow water to soak down through it until the dye is washed out of the soil. This illustrates how alkali lands are reclaimed.

Black alkali (salsoda) is so much more injurious to plants than white alkali that sometimes, when there is but little in the soil, the land may be made good for all crops by putting land plaster or gypsum on the land. Gypsum makes the black alkali "white," that is, it changes it into Glauber's salt, which is much less injurious than salsoda.

FIG. 74. — Greasewood, a plant of strongly alkaline land.

Alkali water, that is, water containing an unusually large amount of alkali salts, should not be used for irrigation if it can be avoided. But if there is no other water and the alkali water is not excessively strong, it may be used, provided it is not allowed to become stronger by evaporation at the surface.

The surface must be kept very loose, and the water applied *plentifully in deep furrows*, so that it will not wet the surface at all. By using *a great deal* of such water, the alkali is prevented from accumulating in the subsoil.

Sensitiveness to alkali. Different plants differ very much in their sensitiveness to alkali. The lemon and orange are very sensitive to common salt. Most legumes and grasses also cannot stand much. Grapes, olives, pears, and apples are much less tender. Deep-rooting plants like alfalfa, carrots, and beets are quite tender when young, but much less so after their feeding roots (see page 15) get deep into the ground. Asparagus will stand a good deal of common salt.

Alkali weeds are wild plants that grow even where there is much alkali, and one should know these plants in order to recognize alkali soils.

"Alkali grass" (figure 73) is one of the commonest and best-known alkali weeds. There are many others quite as good for showing where there is alkali. Such are the "greasewoods" (figure 74), whose leaves are mostly round instead of flat, and several "saltbushes," some of which look very inviting but are so salty that the cattle will not eat them. But alkali weeds are different in kind in different regions, and must be studied for each locality. We may thus often know beforehand what kind of alkali land it will pay to reclaim for cultivation, and how it should be done.

CHAPTER XII

FERTILIZATION AND FERTILIZERS

WHEN all the various operations and precautions described above fail to give good crops, we must conclude that food substances are lacking in the soil, and that we must supply these by putting them on the land. Sometimes even fresh soils ("poor lands") do not naturally contain enough plant food to supply more than one or two crops.

Farmyard manure. The fertilizer which has been used longest and is justly very highly prized is *stable* or *farmyard manure*, the offal from farm animals, mixed with straw or other litter with which these animals have been bedded. This manure, of course, contains all that the food of the cattle has taken from the land, less what has been used for the growth and products (milk, eggs, etc.) of the animals themselves. By putting the barnyard manure back on the land (which should always be done), we return to the soil a very large part of what was taken from it by the crops. But, of course, a part — so much as has been sold from the farm — is not returned. So even if we put back all the stable manure, there will be a lack or *deficit* in the return, which will have to be made up some time.

We should, therefore, make it a rule to put back on the land *all* offal; and this should never be burned, because burning wastes into the air the nitrogen that should nourish the crops and the humus that should improve the land. Weeds and vegetable and animal trash of all kinds can be put into piles with some earth. These piles should be kept moist, so as to make them decay into " compost," a very useful fertilizer.

Farmyard manure, of course, supplies all the kinds of food taken by plants from soils (see page 57), but only in small amounts, and largely not in a very *available* condition, but its effects last several years. When we want quick action we often have to use other fertilizers. We can also get quick action by watering the plants with the leachings or " manure water," which flows out from the manure pile when it is kept wet. We can also stir up manure in water, and water pot plants with it. For this, and for general use, manure should first be " cured " or left to ferment or rot for some months, keeping it moist all the time.

Fresh, strawy manure is often used in the humid region, being left on the surface or plowed in. The frequent rains will then rot it in the soil. But in the arid region this cannot be done, because in the dry surface soil the manure will not rot, but keeps the soil too loose and open, so that crops are injured by heat and dryness. For this reason manure (as well as straw) has in California been burned in autumn.

This is a dreadful waste of valuable plant food. Both should first be allowed to rot in piles kept moist, before being plowed into the land. The soil will then be enriched with humus without making it too "open."

Soil bacteria. But stable manure and compost aid crops, not alone by the plant food and humus they bring into the soil. One of their greatest advantages is that they carry with them a great multitude of bacteria, which act very favorably on the soil. Much of their immediate effect is due to these minute plants, which greatly help the soil-nutrition of plants.

Some of these bacteria take nitrogen, a very valuable plant food, from the air and store it so that the plant can use it. These are called nitrogen-fixing bacteria. Some of them live in the soil, others live in tubercles on the roots of legumes. Read what is said about them on page 263.

Greenmanure. When we can get no stable manure, or not enough, we can with great benefit use green plants for plowing in. Such plants are best grown on the land itself. A crop of weeds will do some good, but it is better to grow legumes such as clover, peas, beans, or vetches. The reason for using these particular plants for greenmanuring is that by means of bacteria in tubercles on their roots (figure 75) they take nitrogen from the air (page 128 and figures 75 and 76). Grasses are not able to do this, and are not nearly as good for greenmanuring.

Green plants decay much more rapidly than straw or strawy stable manure. They soon wilt down and so make no trouble for a seed bed, a week or two after plowing in. They bring with them, of course, all the

FIG. 75. — Root tubercles of square pod pea. The small figure shows the appearance of the bacteria under the microscope.

plant food the crop had taken from the land; and if grown during a California winter, no crop-growing time need be lost. But a greenmanure crop growing in an orchard during summer would be as

bad as a crop of weeds, as it will waste too much moisture.

Commercial and mineral fertilizers (figure 76). If we could always get enough stable manure, we should need no other, and nothing else was thought of until it was found that it was impossible to get enough manure to go around, and keep up profitable crops in the fields. The reason is that a portion of the fertility of the land is always carried off in what is sold from the farm.

When this was recognized, chemists analyzed stable manure and plants to find out what is needed, and then tried to find other materials from which potash, phosphoric acid, and nitrogen might be obtained. When it was found that *bones* contain much phosphoric acid, they were ground, and bone meal became a much-prized fertilizer. Bones were brought even from South America and other countries to Europe. Then *guano*, the dung of sea birds living on islands off the coast of Peru, was brought and long used in large quantities; but now there is but little guano left. It supplied the same substances as stable manure, but in much more effective form.

Chile saltpeter. Soon after, it was found that there are in Chile large deposits of saltpeter, which contains the most effective (nitric) form of nitrogen. Many millions of tons of this *Chile saltpeter* have been and are now being brought from Chile, and have greatly helped to keep up the crops of Europe. Much is also now used in the United States.

Potash salts. Then it was discovered that near Stassfurt in eastern Prussia there are, alongside of common or rock salt, enormous deposits of *salts of potash;* and these are now being mined in large amounts and supply the entire world.

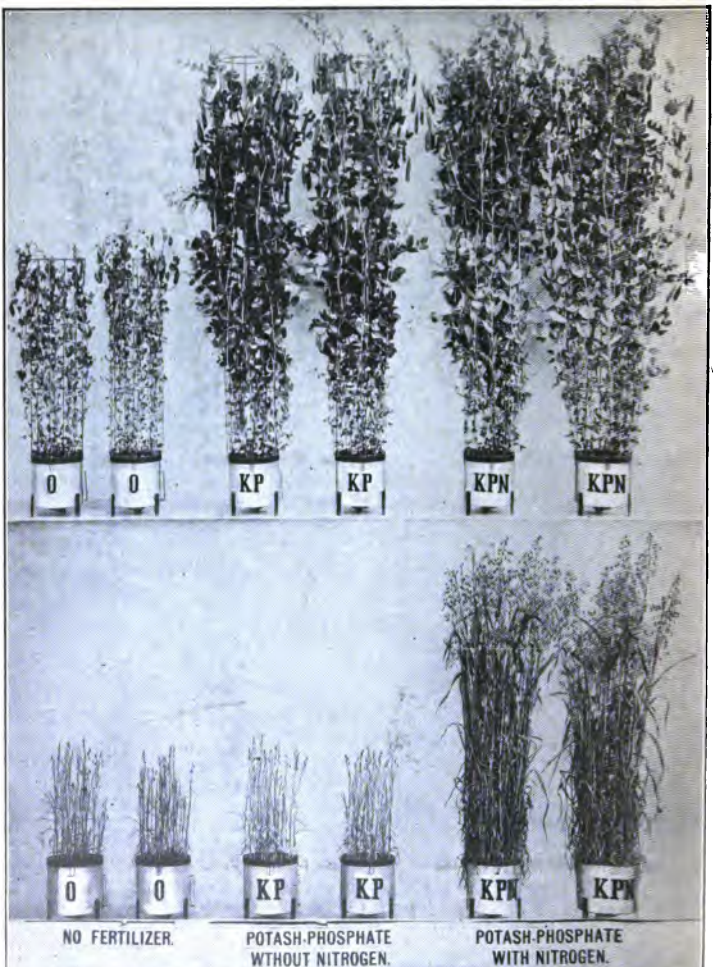

FIG. 76. — Effect of fertilizers. Both oats and peas are helped by potash phosphate. But the pea has much less need for nitrogen than the oat, because the pea can take nitrogen from the air by means of the bacteria in its root tubercles.

Phosphorite rocks. About the same time it was found that in many places what had been taken for simple limestone contains so much phosphoric acid that this "*phosphate rock*" can be used in place of bones, which are often scarce. So it has become possible to make up for the insufficient supply of stable manure, from rich mines in Florida, South Carolina, and Tennessee, and elsewhere.

The supply of phosphoric acid is now also being increased by using "*phosphate slag*" from iron works smelting certain ores. And several methods of getting the abundant nitrogen from the air for use in fertilizing have been invented and are being operated.

So we can make up the deficiency of stable manure by means of these mineral fertilizers, and we can strengthen what manure we have by adding them to it. Only, Chile saltpeter must never be used *at the same time* as stable manure, but some weeks after. And in general it may be said that good production cannot be permanently kept up with these mineral fertilizers alone. They must be supplemented by the use of stable manure, greenmanuring (see p. 141), or the use of some other material that will put humus into the soil, such as muck or peat. Meat scraps, dried blood, and other offal from the slaughterhouses, called *tankage*, may also be used with great advantage.

Fish scrap, the offal from fisheries of various kinds, especially on the North Pacific Coast, is an important material for the manufacture of fertilizers; and fish may also be put directly on the land, to supply especially nitrogen and phosphoric acid. On the shores of New England a small kind of fish called menhaden is caught by the ton in nets and used as a fertilizer by farmers. *Seaweeds* also are often used to add to the supply for compost heaps. Slaughterhouses also supply "superphosphates," bones made soluble

with sulphuric acid; the same are also made from rock phosphates.

Liming. There should always be plenty of lime in soils, because most crops grow best in land having from 1 to 4 per cent of lime. We can know that there is lime enough when clovers or other legumes grow on the land. When mainly rough grasses and sedges grow, the soil itself is sour, and should have lime put on it.[1] For this we can use air-slaked lime, or else marl, a soft, limy rock often found in California, and in the coast ranges of Oregon and Washington. East of the Sierra Nevada and Cascade Mountains, in Oregon and Washington, southern Idaho, Montana, and from Nevada to Wyoming and south to New Mexico and Arizona, almost all soils have plenty of lime, except sometimes in swampy places along the rivers and in the high mountains. We can tell that there is plenty of lime in soils when they have many legumes (plants with flowers like the pea, such as lupins, loco weed, clovers); also when there are plenty of wild roses, as on the plains of Washington and Montana, where *rose land* is known to be the most productive. Such lands do not need liming.

[1] When soils are sour they make *red* spots on moist, *blue* litmus paper put on the wetted soil. When *red* litmus paper is turned *blue* after half an hour, it shows that enough lime is in the soil. If it is turned blue *at once*, it shows that there is black alkali, and plenty of it.

Liming makes heavy clay or adobe soils easier to work, also helps sandy soils to maintain crumb structure (tilth, see page 63) and to form humus.

How to use fertilizers. The best fertilizers will be of no use if the roots of the crops cannot reach them. So, if we know that the roots in our land go deep and do not stay near the surface, we must put the fertilizer in deeply also. In humid regions it is usual to put manures on the surface in autumn and let the winter rains wash them partially into the soil before plowing them in. If they are easily dissolved in water (as in the case of Chile saltpeter and potash salts), they need not be plowed in at all. This is because the roots of crops in the humid region remain within a foot or two of the surface.

But in the arid region, where roots go very deep and most of the time have no feeding roots near the surface, all fertilizers except saltpeter and potash salts (which are carried deep enough by rain or irrigation water) should be put in deeply also, so that they may nourish the roots during the growing season.

Generally it is best to spread fertilizers evenly over the entire surface of the land, so as to favor the spread of the roots all through the ground. Leaving stable manure in piles on the fields is bad practice. Young trees are often at first fertilized in a small circle around the trunk in order to push their growth; but this should not be continued. When planting crops in rows or

drills, the fertilizer is also often put in a furrow made before seeding, and then covered with some earth, upon which the seed is put. Most fertilizers should not touch the seed, as they may kill it; they should always be well mixed with earth first.

Worthless stuff is often sold at high prices for fertilizer. To prevent this some states (California, Oregon, Washington, and others) have fertilizer laws. In these states the buyer can find out just what the fertilizer is worth from an analysis which is made by the state officials and which must be pasted on each sack.

CHAPTER XIII

THE WEATHER

No matter how well we may have attended to all the things mentioned as favoring good crops, unfavorable *weather* may greatly reduce, or even destroy them.

What we call **weather means chiefly four things:** 1. Heat and cold, or " temperature." 2. Sunshine or cloudiness. 3. Rain, snow, or hail. 4. Winds. We call the weather good or bad according to whether we like it, or it favors what we wish to do or to have done.

Where irrigation is not practiced, as in the Eastern states, farmers depend entirely upon rains for their crops. There, a failure of rain for a few weeks during the growing season may almost destroy the crop, because the soils are shallow and the roots are near the surface. So in the arid regions we have in irrigation, and in our deep soils, great preventives of crop failures. Yet even *with* irrigation, a hot, dry norther and hot sun may sometimes shrivel the heads of grain, or the leaves or flowers of fruit trees and vines. Or a " cold snap " or frost may damage or wholly destroy fruit blossoms or vegetables. Or an early-sown crop, just

sprouted, may be ruined by a spell of dry weather. If the farmer could have known that such a dry spell was coming, he would have waited to sow until later in the season. But how could he know?

We have long tried to find out how we may predict the weather a long time ahead, but we have been unable thus far to forecast it with any certainty for more than one or two days ahead; except that in most of the arid states there is almost a certainty that, outside of the mountains, there will be no rain of any practical consequence during from three to six months of summer. Yet rains do sometimes come, and finding the crops stacked in the open fields they may do a great deal of damage.

Forecasting the weather. The enormous importance of knowing beforehand what the weather of a season is going to be has brought about many attempts to discover a sure method of forecasting it. Until within the last fifty years, almanacs claimed to give good weather predictions for every month of the year, in advance. Such predictions were guesses based upon the average records of past years, often colored by a foolish belief in the influence of the phases of the moon. Many farmers believe in this influence even yet, although accurate observations for many years have failed to show any truth in this belief. It is now thought that the study of the sun's changes (as to light, heat, and magnetism) may help us to understand the weather

changes on the earth; but as yet we know little that is definite.

Meanwhile studies of air movements and winds, and of the moisture, heat, or cold they carry with them are constantly being made by the United States Weather

FIG. 77. — Observatory on Mt. Rose, the highest on the Pacific (10,000 feet). It is upon such observatories that future progress in weather study largely depends.

Bureau, and elsewhere in the world. These studies help us to understand weather changes. Thus we now know that both storm and clear-weather areas are usually in the form of great circular whirls of air (cyclones) fifteen hundred to two thousand miles across. They

enter the North American Coast from the West, mostly in British Columbia or the state of Washington, and move in a direction south of east. Sometimes they move at the rate of six hundred or more miles a day, and crossing the mountains and Great Plains, turn in a northeast direction near the Great Lakes and reach the northern Atlantic coast in from five days to a week or more. Or, starting farther south, they may travel southeast to the Cotton states.

So the Eastern states get weather warnings several days ahead by telegrams from the Weather Bureau stations on the Pacific Coast. But the stations on the Pacific Coast have very little warning of this sort in regard to coming storms moving from the Pacific Ocean. Other storms are known to start in the Gulf of Mexico and move northeastward in the Atlantic states; they are often of great violence, like that which partly destroyed Galveston in September, 1900, and Key West in October, 1909.

The United States Weather Bureau sends warnings of all coming storms as early as possible, and also notifies communities of coming frosts and floods. Frost warnings are of special importance to California farmers.

Weather maps. The weather conditions in the United States are each day shown on maps, which are sent out by the Weather Bureau (figure 79), and we ought to learn to understand these maps well, so as to make use of them.

On the daily weather maps we see curved lines (sometimes circles) called isobars. These lines connect points having the same air pressure or "barometric pressure." Low pressure is associated with rain or wind, and high pressure means fair weather. To measure it we use a glass tube three feet long. This we first fill with quicksilver, then close it with the thumb and set it up, with its open end downward, in a cup full of quicksilver. The quicksilver in the tube then falls down from the closed end of the tube until it stops at about thirty inches above the quicksilver in the cup. When a storm is coming the quicksilver in the tube falls, sometimes as low as twenty-eight inches; in fair weather it usually stands at thirty inches or over, sometimes as high as thirty and one half inches. When it falls fast, a heavy storm is coming; when slowly, usually rainy weather; after which it rises again. So when we know how the barometer stands west of us, we know what kind of weather is coming for many hours beforehand.

We live like fish on the bottom of the air-sea, which is at least forty miles[1] high, and probably a great deal more. When we push down a cork in water it rises as soon as we let it go, because it is lighter than water.

[1] Recent observations by the Belgian Government with sounding balloons showed an air pressure of 0.67 inch at a height of about 18 miles. The highest sounding balloon ascension in North America occurred on May 7, 1908, from St. Louis, under the direction of Professor Rotch, when the height of 11 miles was reached.

A balloon rises in air because it is lighter than air. When we go up in the basket of a big balloon, we carry a barometer. The higher we go the more the mercury falls, because the air pressure gets smaller. So the barometer tells us just how high we are above the earth. If we could go to where the air ends, the quicksilver in the glass tube would fall until level with that in the cup, because there would be no more air pressure.

If we look at figure 78, we see on the Pacific Coast the word LOW. This means that in this region the air pressure is low, as shown by the barometer. A similar region is seen on the Atlantic Coast. Midway between the pressure is high, as shown by the word HIGH. The wind blows away from the HIGH and toward the LOW, as shown by the arrows. This is what we should expect. Air moves, just as water does, from the place of greater pressure to the place of less pressure.

The map shows us that a storm is entering the country from the west. Its center is at the word LOW. In front of this center (to the east and south) rain is falling. Still further ahead of it low rain clouds are seen, and the temperature is rising. Still further east of it we see high feathery clouds, and further still, clear sky.

Behind it (to the north and west) we see clearing weather. On the Atlantic Coast, behind the storm which is just leaving the country, we also see clearing weather, then clear sky and falling temperature.

FIG. 78. — **Map showing a storm entering the country (on the Pacific Coast) and one leaving it (on the Atlantic Coast). A track of a summer storm and one of a winter storm.**

"Weather signs." From ancient times certain appearances of the sky and clouds, and *feel* of the air, have been used to foretell the weather, at least for the next day, or even longer. Many such signs and rules are based upon long experience. Some hold good for one place, while others are more general. Thus for thousands of years it has been held that pink or "rosy" cloudlets at sunset promise clear weather for the following day, while a gray, or "angry" lurid red, sunset foretells rain or storm. The same is mostly true of such clouds at sunrise. The gathering of a cloud-cap on certain mountain peaks is held to be a sure sign of "bad weather" for mountain climbing, while a cloudlet like a weather vane being reeled like a bobbin by the wind from a mountain peak means continued good weather.

In the East the croaking of the green tree frogs is held to mean a coming rain; but in California the green tree frog croaks all through the dry summer. In Europe the country people put much faith in a frog which is kept in a small water tank in which a branch is placed; when the frog stays in the water, it will go on raining, but if it mounts up on the branch, the sky will clear.

In the Mississippi Valley a heavy, "muggy" feel in the air, which makes it hard to breathe, will generally indicate that a thunderstorm is coming, long before a cloud is seen. The breaking of the storm quickly removes the "mugginess."

WEATHER MAP.

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE.

WILLIS L. MOORE, Chief U. S. Weather Bureau.

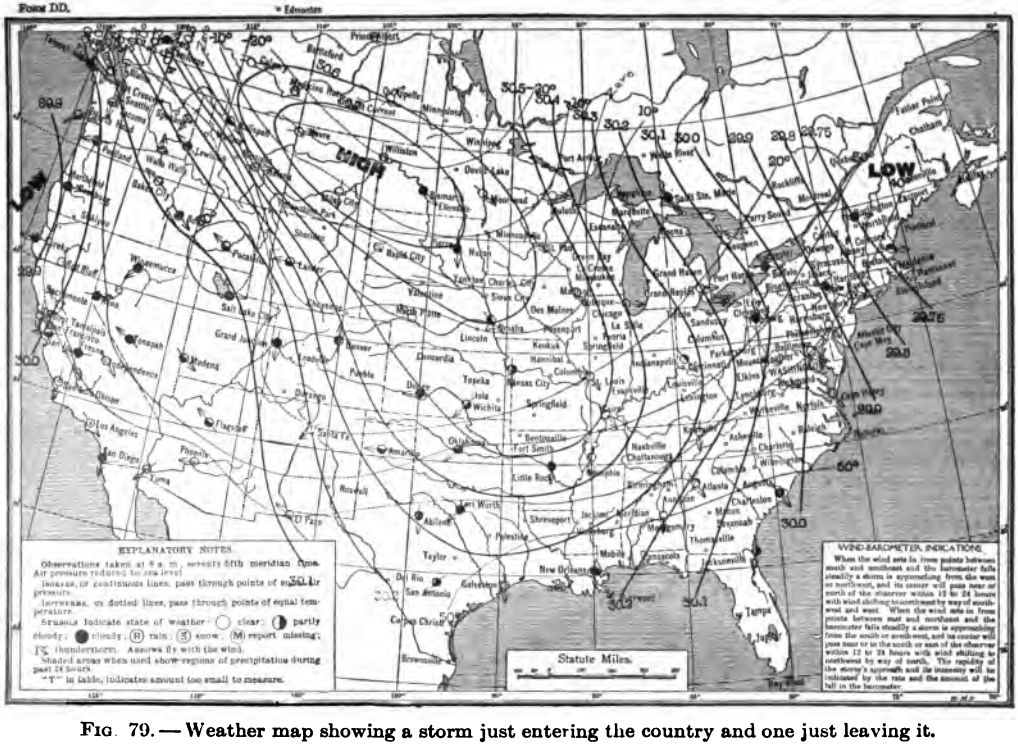

FIG. 79. — Weather map showing a storm just entering the country and one just leaving it.

Fig. 80. — Cumulus cloud bringing rain.

Often these weather signs agree very well with the indications of the Weather Bureau instruments, but there are many exceptions, which can only be corrected by the wider observations of the Weather Bureau. Still, it is well for everyone to watch the weather signs, particularly in the mountains, where the weather is apt to be very local and out of the range of Weather Bureau stations.

As has already been said, the falling of the barometer gives the best warning of a coming storm.

CALIFORNIA WEATHER

As there are no weather stations out in the Pacific Ocean, we cannot have weather warnings in California as far in advance as in the Eastern states, but only twenty-four to thirty-six hours ahead. Sometimes the storms come to us straight from the sea and surprise us.

Storms that bring rain to northern and middle California do not always reach to southward of the Tehachapi Mountains, which form a kind of weather divide. But Los Angeles and the rest of southern California sometimes get storms moving from the southwest, known as Sonora storms, and so occasionally have rains in summer. Generally, however, rains stop in California about the beginning of May, and do not return until the middle or end of September, so that there is dry weather during five or six months of the

FIG. 81. — A view from Mt. Tamalpais. As far as the eye can see a great ocean of fog gleams in the bright sunshine. Its surface is upheaved in changing billows of white.

year; while the growing season is from November to May. In summer the storms entering British Columbia from the west pass so far to northward that they do not touch California, but in winter they pass farther south and so give us our winter rains. This is shown in the two storm tracks in figure 79.

Along the coast from Santa Barbara to Cape Mendocino, in July and August, there are heavy fogs, only from fifteen hundred to two thousand feet in height (figure 81), caused by the moist and warm air from the sea crossing the cold water current which comes down along the coast from the north. Above these cool fogs the air is warm and clear, and the fog quickly dissolves as it reaches the warm air which prevails all summer in the Great Valley. But so long as these fogs come through the Golden Gate with a west wind, no rain need be looked for, however dark the sky. The hot air of the Great Valley, rising on the Foothill slopes, causes the indraught through the Golden Gate and over the Coast range. This in the Sacramento Valley causes a south (up-valley) wind, in the San Joaquin Valley a north wind (in this case also up-valley), which cools the afternoons. In winter heavy wet fog sometimes covers the Great Valley for weeks.

At irregular times, hot, dry north winds (northers) sweep over the whole of California in summer, doing damage to crops. They seldom last more than three days. Similar winds in winter are very cold.

At the south end of the San Joaquin Valley, near Bakersfield, California, the yearly rainfall is only about four inches, while at the north end of the Sacramento Valley, near Redding, it is over twenty-four inches; at Sacramento about nineteen only, at Fresno about ten. So irrigation is most needful in the San Joaquin Valley. In southern California, Los Angeles has about fifteen inches of rain per year, Riverside about ten. But there is much naturally moist or "sub-irrigated" land.

From Cape Mendocino northward along the coast the climate changes. There are summer rains, just as in western Oregon and Washington. But east of the Cascade Mountains in Oregon and Washington there are rainless summers, as in California. In the higher mountains thunderstorms (figure 80) bring rains in summer when clouds gather around the peaks. These are sometimes "cloud-bursts," when the rain falls so heavily that it cannot soak into the soil, and rushes down the dry cañons, forming a wall-like wave of water which sweeps all before it. In the lowlands of California thunderstorms are quite rare.

WEATHER IN OREGON, WASHINGTON, AND THE GREAT-BASIN STATES

As already said, heavy summer rains prevail on the coasts of Oregon and Washington, west of the Cascade Mountains, except that in the Willamette Valley there

are often two months of clear summer weather (in August and September) at harvest time. In eastern Oregon the Blue Mountains bring some summer rainfall, as does the Bitter Root Range in eastern Washington and northern Idaho. In Montana the figure for the total rainfall seems enough to render irrigation unnecessary, but as the twenty to twenty-four inches fall all through the year, the short growing season compels the use of irrigation over most of the state. Fortunately the great Missouri and Yellowstone and their tributaries afford abundance of water, and magnificent crops are thus grown on the rich soils. The mountain ranges cause many local summer rains, thunderstorms, and occasionally "cloudbursts," which do not wet the soil to any great depth.

As the weather in autumn gets cold enough for snow before the summer drought ends, grain in the Pacific Northwest east of the Cascades is not sown in autumn, but in early spring. The severely cold weather of winter "blizzards" requires the selection of specially frost-resistant fruit and forest trees for the northern portions of Washington, Idaho, and Montana, as well as for Alberta, Saskatchewan, and the adjoining country.

Chinook wind is the name popularly given to a comparatively warm, dry wind which sometimes comes suddenly, following a severely cold "blizzard" (especially in Montana and the Canadian Northwest, Wyoming, and Colorado) and blows northeastward over the Plains. These warm winds do not come from

the Pacific Ocean, but are formed whenever a moist wind crosses a high mountain range and, having lost most of its moisture in going up the west slope, comes down on the east side of the mountains, and gets warmed by compression as it descends; for pressure always causes a rise of temperature. The temperature of these winds rarely rises above 40 degrees Fahr., but when the rise occurs from 30 degrees below zero within a few hours, or less, it makes us think the wind quite warm. The Chinook[1] sometimes saves trees, crops, and even people from being killed by cold.

WEATHER IN THE GREAT BASIN

Farther south in the Great Basin, in Wyoming, Utah, western Colorado, and New Mexico, the total rainfall in the level country, which is from three to four thousand feet above the sea level, ranges from twelve to fifteen inches; so that where irrigation water cannot be had, "dry farming" (page 49) is the only way to raise crops. This means that the soil surface must always be kept open for the rains to soak in, and made loose again after rains by harrowing, if a crust has formed. In this way very good grain crops can be grown at least every other year, as the soils are very rich.

[1] The word Chinook is now applied in different parts of the country to warm "foehn" winds. Originally the term was applied to a northwest wind from the coast region inhabited by the Chinook Indians.

CHAPTER XIV

WEEDS

ANY plant which grows where it is not wanted is a weed. "A weed is a plant out of place." It is usually only when plants are carried away from their own country into new and very favorable conditions, that they become troublesome weeds. All the worst weeds of the Pacific slope come from Europe or the Eastern states. The seeds are carried by ships or by railway and quickly spread over the country. If we could keep a sharp watch and kill them out before they get a good start, much trouble would be saved.

Weeds are of two kinds:—

(1) Annual weeds, which set seed the first year of their growth and then die.

(2) Perennial weeds, which do not die at the end of the first season of growth. Their stems or roots live underground until the next season, and then grow up again. They can only be got rid of by cutting them down as fast as they appear above ground. If this is done for a season, they will disappear. But it will not do to stop this work even for a short time, or they will make a fresh start.

Weeds in lawns and gardens are sometimes killed

by poisons. In lawns gasoline is used; enough is placed at the root of the weed to kill it. It soon evaporates and does not injure the grass. Along the roads and sidewalks arsenic or petroleum may be used. They stay in the soil and prevent anything from growing where they have been placed. A 15 per cent solution of iron sulphate applied with a sprinkler often kills weeds in a lawn or grain field without hurting the grass. Poisons should never be handled by children.

ANNUAL WEEDS

Annual weeds are very easily got rid of, if they are not allowed to go to seed. Not a single plant should be allowed to blossom or set seed if it can be helped. The best time to kill them is when they are tiny seedlings. But many people do not recognize them at this stage. For this reason pictures are given here of several common weeds at an early stage of growth. It is important to recognize and destroy all kinds of weeds at this stage.

Many farmers pay no attention to the little "summer weeds," because they are so small. But as they produce a great deal of seed it is very important to destroy them. The little wheels of bur clover, knotweed, Napa thistle, pigweed, and filaree, which lie close to the ground and are hardly noticed in summer, cause a great deal of trouble later on.

Cocklebur, or clotbur. The different sorts of cocklebur are too well known to need description, but the seedlings are not usually recognized. They are said to be poisonous when eaten by stock. The burs fasten themselves to animals, which scatter the seeds far and wide. There are two seeds in each bur, and it is said that one grows the first year but the other will not germinate until the following year. Thus the plant has a double chance to survive.

Pigweeds. Figure 82 shows one of these in the early stage, in which it is easily killed. Later on the root gets very tough and woody, and is hard to get out of the soil.

FIG. 82. — Young plant of pigweed. (About natural size.)

One of the pigweeds, when dead and dry, is loosened by the fall winds, and goes rolling and tumbling over the ground, scattering its seeds. On this account it is called "tumble weed." There are a number of different "tumble weeds."

Knotgrass, or bird grass. This is a very common weed all over the United States. It mostly lies flat on the ground and yields a great abundance of black seeds very much liked by canaries. These will sprout even in very dry weather, so that the weed can spread

very rapidly. After the weed dies a perfect forest of little plants comes up where it lay the year before. If these are allowed to grow, their tough, wiry roots make it very hard to kill them.

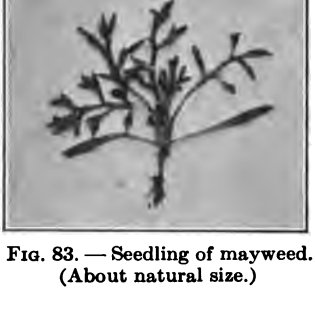

FIG. 83. — Seedling of mayweed. (About natural size.)

Mayweed, or dog fennel. This is a great pest in the East, and is rapidly spreading in the Pacific states. Its early stage is shown in figure 83. It grows two or three feet high, and is completely covered with white daises with yellow centers. The seeds are light and are scattered everywhere by the wind.

Groundsel. This weed has about the same power to germinate in the dry summers as the bur clover has. It should be killed in the early stage shown in figure 84. Its later leaves are of much the same shape as those shown in the figure. It has yellow flowers and fluffy white seeds, which may be carried a long distance by the wind.

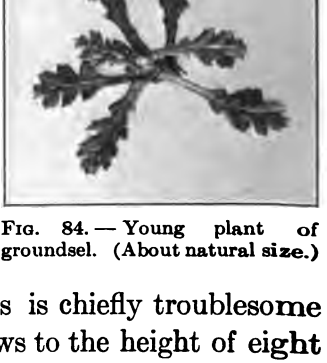

FIG. 84. — Young plant of groundsel. (About natural size.)

Horse weed (erigeron). This is chiefly troublesome in irrigated lands, where it grows to the height of eight

feet and forms thickets. It resists alkali in the soil surprisingly well. The flowers are small and yellow. The seeds fly by means of white down.

Sow thistle. Figure 85 shows an early stage. The later leaves have nearly the same shape as those shown here. The flowers are yellow and produce seeds which fly on the wind. The juice looks like milk.

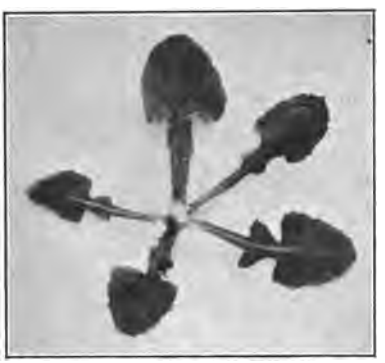

FIG. 85. — Young plant of sow thistle. (About natural size.)

Mallow, or cheeses. The seedling is shown in figure 86. The plant is very hard to get rid of as it produces a great many seeds, and these germinate even if the plant is cut down while still green. They fall into cracks in the soil, where they germinate, and come to the surface even in midsummer. It has been recommended for forage, but animals do not readily eat it.

Plantain, or rib grass. This is common everywhere, and is very troublesome in irrigated lands. The root is tough and hard to cut. Unless the cutting is deep, new leaves will be sent out. When the plants are small (figure 87), they are easily destroyed.

Chickweed and poor man's weatherglass (pimpernel). These two weeds, like those already spoken of,

form an exception to the rule that after the rains have stopped the farmer in the arid region may consider the weed fight over for the season.

The poor man's weatherglass is so called because the flowers close just before rain. This plant is some-

FIG. 86. — Seedling of mallow. About natural size.

times called "poison chickweed," because it hurts canary birds when eaten.

Filaree. The filaree (alfilerilla or alfileria) also germinates and grows during the dry months of summer, and in this respect is like the Napa thistle.

There are two kinds of filaree, one of which is eagerly eaten by animals and makes excellent pasture. This is the red-stemmed filaree. Many people do not distinguish between it and the musky (or "stinking") filaree which

animals will hardly touch. The difference between them is well shown in figures 88 and 89. In the spring the musky filaree grows faster than the other and is easily known by its coarse, rank look. It has pale stems and leaf stalks, while in the other the stems and leaf stalks are red (figures 88 and 89).

FIG. 87. — Young plant of plantain, or rib grass. About natural size.

As the plants get larger the differences are seen clearly. The leaves of the red-stemmed are seen to be much more cut up than those of the musky filaree. The calyx or outside covering of the flower of the musky sort does not have the fine bristles which are found on the calyx of the red-stemmed.

In grain fields filaree sometimes completely covers the ground after harvest. Filaree has a tough, wiry root, which goes deep into the soil, and a sharp tool is needed to cut it. If not cut off below the lowest leaf, it makes new branches which bloom and set seed under the very feet of the cattle.

The seeds of filaree have a wonderful way of boring

FIG. 88. — Musky filaree at the left. Red-stemmed filaree at the right.

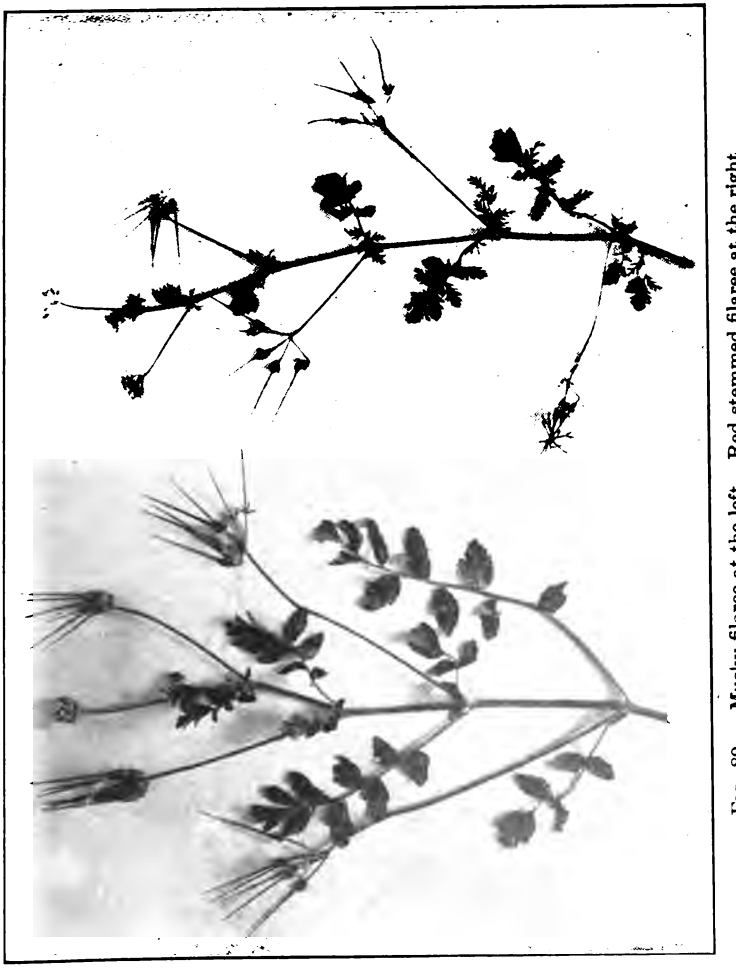

FIG. 89. — Musky filaree at the left. Red-stemmed filaree at the right.

into the soil. You can see how this is done by putting them on the surface of moist soil or moist cotton (figure 90). The suface of the soil should be loose to get the best results.

Sheep Sorrel. This little plant is very hard to get rid

FIG. 90. — Filaree seed burrowing into moist cotton.

of when once it takes possession of a field. In its early stages, as shown in figure 91, it is easily killed.

West of the Sierra Nevada the following annual weeds are especially important.

Napa thistle. The Napa thistle (called also tocalote and prickly tarweed) is one of the worst annual weeds

in California. It differs from most other weeds in giving the farmer no rest in summer. Starting in early spring, it matures seeds in May. These germinate when it is so dry that scarcely anything else will grow,

FIG. 91. — Sheep Sorrel. (About natural size.)

and soon produce another crop of seed. This second crop of seed may also grow and produce seed in December.

In pastures it is even worse than in cultivated fields, for it soon kills out the grass and takes complete possession of the land. It perfectly illustrates the survival of the fittest.

Wild mustard and radish. The black mustard and yellow mustard (also called white mustard and yellow turnip), with their masses of yellow flowers, are very well-known weeds. In the seedling stage, as shown in

FIG. 92. — Seedling of wild mustard. (About natural size.)

figure 92, they are easily killed. Notice how the first two leaves differ from the later ones.

The radish looks very much like the mustard in the seedling stage, but its flowers are purple, pink or white.

The roots of mustard and radish are very tough and hard to get rid of. The radish in California may live over to the next season, and even longer.

Mustard plants sometimes form thickets growing to a height of eight feet or more.

Milk thistle. This is one of our most beautiful weeds, growing to the height of five or six

FIG. 93. — Seedling of milk thistle. (About natural size.)

feet. It has large spiny, deep green leaves mottled with white. The flower heads have strong spines and purplish flowers. The seeds are black, and are eaten

FIG. 94. — A small plant of turkey weed. (About one third natural size.)

by ground squirrels and birds. They have a white, fluffy parachute to enable them to fly with the wind.

This weed should be destroyed in the seedling stage shown in figure 93. Notice the difference between the green seed-leaves and the foliage leaves, which are

streaked with milky white. It should always be mowed before it begins to set seed.

Turkey weed. This plant, also known as turkey mullein, gets its name from the fact that turkeys are fond of the seeds. It was called Yerba del pescado by the Spaniards because the Indians used it to catch fish. When it was placed in small streams or pools, the fish were stupefied and could be caught by hand. The leaves have a peculiar odor.

It is remarkable because it stands dryness better than almost any other weed. It flourishes even in the desert.

FIG. 95. — Seedling of bur clover. (About natural size.)

Plants which can endure dryness usually have their leaves covered with wax or hairs, which help to keep the water from escaping. As figure 94 shows, the plant is so thickly covered with hairs that it looks gray.

Bur clover. This plant has the power to germinate in dry weather, but not to such an extent as those spoken of above. It is very hard to get rid of, because its roots go deep and are hard to kill out. They may even live over until the following season, so that the plant becomes perennial. The best time to destroy it is when

it first comes up, in the stage shown in figure 95. Notice the different forms of the leaves on the same plant at this stage.

When the pastures dry up, the burs often cover the ground, sometimes an inch deep, and the cattle eat them and grow fat on this "dry pasture." Sheep are kept away from such pastures, because the burs damage the wool.

Annual grasses. The *darnel* or poison darnel is a weed in grain fields, and many people believe that it changes itself into wheat, barley, oats, or whatever the grain may happen to be in which it is growing. This is a popular error, as hard to get rid of as the weed itself.

The "*foxtail*," or "barley grass," which works itself into clothing, into the wool of sheep, and into the nostrils and ears of animals, is one of the barley grasses, and not a true foxtail grass.

PERENNIAL WEEDS

Perennial weeds are the hardest to get rid of. If the tops are cut off just as often as they show themselves above ground, and this be kept up for a season or so, the weed will disappear. But it will not do to let them get even a slight start, or all the work may go for nothing.

White morning-glory, or bindweed. This is one of the worst perennial weeds. Its long underground

stems are very difficult to destroy. Only constant cutting will check it.

Perennial Grasses. — The worst of these is the famous Johnson grass. The salt grass is also troublesome in alkali soils.

POISONOUS PLANTS

Poison oak, or poison ivy. While not poisonous to animals, it is so to many people. The poisonous sub-

FIG. 96. — Poison oak or poison ivy. The leaves are in groups of three. The berries are shown at the left.

stance is an oil, of which any alkali will destroy the poisonous action. Hence, if the skin is washed with

weak Javelle water (directions for making which are found on every package of chloride of lime), with weak ammonia water, common soda, or hyposulphite of soda, the irritation, itching, and other effects of the poison soon stop. If the treatment be given as soon as one comes home from a walk, the poisoning will be prevented.

It is not necessary to touch the plant in order to be poisoned. When the plant is in blossom, the oil may be carried by the pollen which floats on the wind. Or the oil may be carried by the wind from the smoke of bonfires in which the plant is burning. Or it may be carried by clothing or anything else which has touched the plant.

It is easy to recognize the plant by its leaves, which are always in groups of three. There is no other plant in the woods which looks like it. The leaves turn a beautiful red in the fall, and are often picked by people who do not know that the plant is poisonous.

It is a perennial plant with long underground stems. The only way to get rid of it is to have it dug out by some person who is not affected by the poison. One must be careful about supposing that he is not affected, for it sometimes happens that a person who thinks he is safe takes the poison while perspiring freely.

The plants are sometimes killed by pouring sulphuric acid on the roots. The acid does not long prevent grass or other plants from growing on the spot, as many

poisons (such as arsenic) would do. The acid is a poison and will burn flesh or clothing and should never be handled by children.

Other Poisonous Plants. Among the plants which are said to be poisohous when eaten by animals (or by man) are: cocklebur (in the two-leaved stage when eaten by animals), poison lupine, camas, milkweed, cornflower, nightshade, sneezeweed, dogbane, baneberry, poison hemlock, wild cherry. Hay containing much horsetail is said to be poisonous to animals. (Wyoming Experiment Station, Bulletin 73; Idaho, 37.)

BULLETINS ON WEEDS

Consult California Experiment Station Annual Report, 1890, page 238; Nevada, Bulletins 21, 22, and 38; New Mexico, Bulletins 13 and 16; Oregon, Bulletin 19; Washington, Bulletin 34; Wyoming, Bulletin 31.

CHAPTER XV

FOES AND FRIENDS OF THE PLANT[1]

EVERYONE who grows plants must fight against the hungry insects which are eager to eat them. But by knowing just how to apply the proper remedies, insects may be almost entirely prevented from harming our plants.

Some insects eat the leaves. They may be poisoned by spraying with lead arsenate or Paris green. Directions for making sprays are given on page 412. The leaves should be covered with fine drops like dew. Unless Paris green is properly made, it injures the leaves. A certificate from the State University is required for Paris green sold in California, and no one should buy it without seeing this certificate.

Some insects suck the juices from leaves by thrusting their beaks into them. These sucking insects are not injured by lead arsenate, because it stays on the *out*side of the leaf, and they take their food from the *in*side. We must therefore spray the insects rather than the

[1] The teacher is especially advised to take up only a few typical forms, which can easily be obtained in his locality, for illustration.

leaves. For this we use a spray of soap and kerosene, or some other substance which does not need to be eaten in order to kill them, but kills them merely by getting on the outside of their bodies. The spray should be applied with considerable force.

Much time and money have been wasted year after year in spraying lead arsenate (and Paris green) upon sucking insects such as plant lice and scale insects.

Some insects feed on the roots. They may be starved by keeping the land bare of crops for a time, or by growing a crop which they cannot eat. In some cases they may be killed by leaving poisoned food on the ground where they can easily find it.

Some bore into the wood and bark. For these there is no good remedy. They are sometimes dug out by hand, and sometimes killed by carbon bisulphid.

Poisonous gases are used to kill all sorts of insects, either out of doors with the aid of a tent placed over the tree, or indoors in a closed box. Most states have a quarantine station through which plants coming from outside must pass. There the plants are usually exposed for a short time to poisonous gases to kill any insects which may be on them. This is called fumigation.

Household plants are often attacked by insects. The best way to treat them is to brush the leaves and stems carefully with a toothbrush dipped in soapsuds.

Insects form one of the most interesting parts of nature study. "The life stories of many insects,

if told in detail, would rival in variety and interest many a famous fairy tale." There are many insect books which tell these stories, but in many cases the insects are quite different from those on the Pacific slope. Some which have to do with our own insects are found in Kellogg's " Insect Stories."

BUTTERFLIES AND MOTHS

The butterflies (figure 97) and moths (figures 98 and 99) which visit flowers are very fond of honey, and if we watch them at work, we can easily see the long tongue which they use to reach the sweet nectar lying at the bottom of the flower. When they are not feeding, they roll up the tongue so that it is out of the way.

FIG. 97. — Alfalfa butterfly.

The butterflies and moths flying about the garden seem to do the plants no harm. In fact they may carry pollen, and so help to make good seed, as we have already learned (page 93).

But the gardener would gladly be rid of them, for

some of them make him a great deal of trouble. They lay their eggs on or near the plants (figure 100). Out of these eggs come young worms or caterpillars, which eat the leaves. And so the gardener looks upon them as his worst foes.

FIG. 98. — Moth clinging to the cocoon out of which it has just come.

When you find worms or caterpillars, you may put them into tumblers or fruit jars with some of the leaves of the plant on which they are feeding, and tie a piece of cloth over the top. Give them fresh leaves of the same kind as often as they are needed. By and by you will

see that they stop feeding; some of them may spin soft silken cocoons in which they stay for some time. One day the cocoon or pupa case will open, and out will come a butterfly or moth. Then you will know to what plant that butterfly or moth is a foe, and you will try to protect your plants against it in future.

Fig. 99. — Sphinx moth.

If you keep the moths in a fruit jar, they may lay eggs. When the eggs hatch out, you may give the young caterpillars some fresh leaves and see what great quantities of food they eat, and how fast they grow. When they are full-grown they may spin cocoons out of which they come as perfect moths. Many moths do not spin cocoons, and none of the butterflies do.

FIG. 100. — Eggs of a California oak caterpillar. (Enlarged.)

The active caterpillar or worm is called a larva. While it is resting and changing into a moth (or butterfly), it is called a pupa. Figure 101 shows a pupa which has no cocoon. Figure 98 shows a cocoon inside of which was a pupa which has just become a large moth.

A moth or butterfly passes through four stages: (1) egg, (2) larva (caterpillar or worm), in which stage it crawls about and gorges itself with food, (3) pupa (with or without cocoon), in which stage it rests and might be thought to be dead, (4) winged insect (moth or butterfly).

FIG. 101. — Pupa of tomato sphinx moth.

The codling moth. If we put some young wormy apples into a fruit jar, we shall after a time see the worms come out and make cocoons. Later we shall see that out of these cocoons come moths which are known as codling moths. They lay their eggs in the orchards, and the first worms which hatch out in the spring enter the apple blossoms and feed awhile in

the young apple (figure 102). After a while they bore their way through the apple and come out, and turn into moths which lay more eggs. The worms from these are called the second brood, and they enter the young apples and feed on them. Several broods may be produced in a season, but a large part of them may be killed by spraying at the right time with lead arsenate.

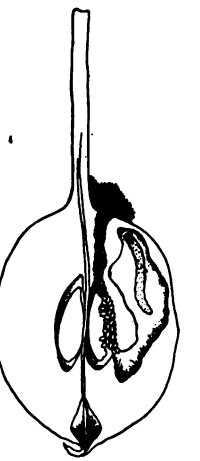

FIG. 102. — Codling moth worm in a young apple.

Enormous quantities of pears and apples are spoiled for the market by the burrows which are seen when the apple is cut. (Arizona Experiment Station, Bulletin 57; California, 155; Idaho, 55, 61; Oregon, 69; New Mexico, 41, 65, 68; Utah, 65, 87, 95; Washington, 68, 77, 81, 86.)

Tussock moth, or horned caterpillar. This caterpillar (figure 103) which attacks apple trees is remarkable for being so little affected by sprays. The best remedy is to destroy the eggs by picking them from the tree. The caterpillars may be shaken from the trees. To keep them from

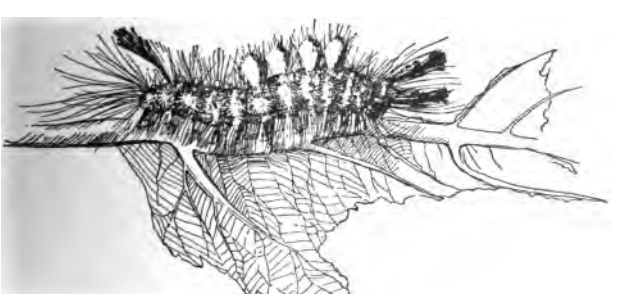

FIG. 103. — Tussock moth or horned caterpillar.

climbing up again, a rope or paper band covered with sticky substance is tied tightly around the tree. (California Experiment Station, Bulletin 183.)

Cankerworm. This is also called the measuring worm or inchworm, because it walks by looping its body along the leaf or branch on which it is walking. When the tree is jarred, the worm drops down and remains hanging by a slender silken thread, by means of which it afterwards climbs up again.

In the early summer the worms burrow in the earth, and later come out as moths of two kinds, one with wings and another without wings. It is the moth without wings which lays the eggs. The moth must crawl up the tree to lay its eggs, and may be caught by a band of sticky paper tied tightly around the trunk.

The potato worm. Everyone knows the burrows of the potato worm as seen in wormy potatoes. The worm develops into a moth which lays eggs on the potato plant or on the potatoes; the worms come out of the eggs and attack the stems or the potatoes.

The infected potato stalks may be known by their wilted appearance, and should be removed and destroyed. During the time of digging and storing, the potatoes should be covered so as not to leave them exposed to the moth. The stored potatoes may be freed from worms by using carbon bisulphid, or by placing them under water. (California Experiment Station, Bulletin 135.)

The peach-tree borer. This is most common on peach and apricot trees, or on prune trees growing on peach and plum roots. It bores into the bark just beneath the surface of the ground, and usually causes masses of gum to appear on the outside of the bark. It develops into a moth which lays eggs on the bark of the tree.

It may either be dug out with a knife, or killed with carbon bisulphid, which may be poured around the base of the trunk and covered with earth. In either case great care must be taken not to injure the tree (California Experiment Station, Bulletin 143; New Mexico, 68.)

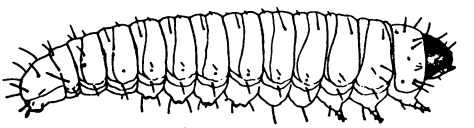

FIG. 104. — Worm (larva) of peach borer. (About twice natural size.)

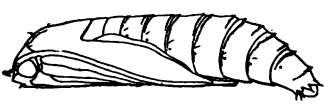

FIG. 105. — Pupa of a peach borer. (About twice natural size.)

Other borers which act in the same way, but which develop into beetles instead of moths, are known to injure fruit, forest, and shade trees.

The peach worm. The peach worm injures the peaches in much the same way as the codling moth does the apple. It attacks also apricots and plums. Figure 106 shows how it looks.

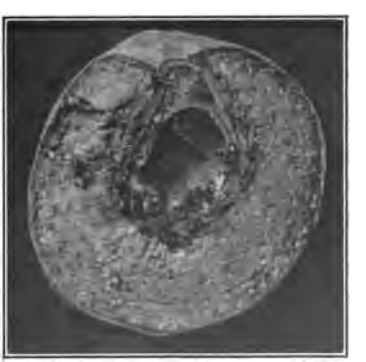

FIG. 106. — Peach worm. (About one half natural size.)

In the fall the young worms bore into the bark, choosing the crotches where the new branches join the older stems. The worm lines its burrow with a tube of silk which sticks out as shown in figure 108. This tube allows the worm to breathe, but protects it against the weather and also against sprays. The tube is covered with tiny crumbs of bark. It is shown, natural size, in figure 107.

It may be checked by a spray of lime and sulphur, if

applied at the right time. (California Experiment Station, Bulletin 144; Utah, 65.)

FIG. 107. — Burrow of peach worm. (Natural size.)

Cutworms and army worms. The same insects are known by both names in California. They spend the winter as half-grown worms and begin to feed in the spring. They attack annual plants at the surface of the ground. Or they attack trees and vines by climbing up to the buds and destroying them: in this case they may be kept in check by poisoned food placed about the base of the plant.

The moths are usually dark-colored, and as they fly by night they are seldom seen. They lay their eggs on the stems of grains or grasses near the ground. The young worms hatch out and feed near the ground during the night, and hide themselves by day. Sometimes they become very numerous. When their food becomes scarce, they leave the fields in

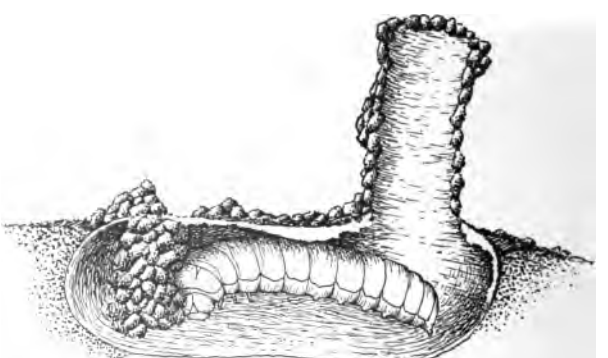

FIG. 108. — Burrow of a peach worm. (Enlarged.)

which they have been breeding, and march like an army over the country, destroying everything green which comes in their way. They are then known as army worms.

They may be stopped by a deep furrow plowed with a straight up-and-down edge toward the field which is to be protected. Very few will be able to crawl up this, and even these may be stopped by fine earth heaped up in a steep slope above the furrow. The worms crawl along the furrow, and if post holes are dug a short distance apart they will fall into them, and may there be killed and buried.

If they get into a vineyard, heavy spraying is necessary to keep them in check. (California Experiment Station, Bulletin 192; Oregon, 38; New Mexico, 68; Washington, 47.)

FIG. 109. — Army or cut worm. (Enlarged.)

Corn worm. This is the worm which does so much damage to cotton in the Southern states, where it is known as the cotton boll worm. With us it attacks corn and tomatoes. The moth lays her eggs on the leaves, where they soon hatch. The young worms look somewhat

like cutworms or army worms. They feed on the leaves and buds and also attack the tassels and young ears of corn. In a short time they reach their full size and then burrow into the ground. After two or three weeks they come out of the ground as moths, which at once lay more eggs. There are several broods in a season.

Clothes moth. The clothes moth is known in every household. It lays its eggs in woolen garments and the young worms hatch out and eat the cloth. You have no doubt seen the silken coverings in which they hide. Chests or closets of camphor wood or cedar are partly proof against these moths. It is not generally known that an ordinary closet or chest may be made partly moth proof by painting the walls with cedar oil (or with oil of lavender or similar oils). The oil is expensive, but the effect lasts a long time. Various substances, including the so-called moth balls, may be used with good effect to protect clothing. Carbon bisulphid may be used to destroy the eggs and worms in clothing which is to be packed away. (Carbon bisulphid is poisonous, and easily catches fire if brought near a lamp.) For information about household insects, send ten cents to the Superintendent of Documents, Union Building, Washington, D.C., for "The Principal Household Insects of the United States."

FIG. 110. — Moth of army or cut worm. (Enlarged.)

BEETLES

If we watch a ladybird about to fly, we see two hard shiny covers lifted up from its back. From under these come two soft transparent wings which unfold and spread out ready for flight. Presently it flies, and the moment it alights, the delicate wings are drawn under the hard covers and tucked in out of harm's way. The hard covers are really a pair of wings. They are for the protection of the wings which do the flying. This is so with all beetles. They really have two pairs of wings, like moths and butterflies, but use one pair for flying, the other for protection.

If you look at the head of a beetle, you see that it has not a long tongue like a butterfly or moth. Instead, it has strong jaws, with which to bite and gnaw. The eggs laid by the beetles hatch out into worms (often called grubs), which sometimes look very much like those of butterflies and moths. After eating and growing for a time the worm or grub turns into a pupa. This does not have a cocoon, as some moth pupas do. The pupa finally changes into a beetle.

Wireworm. When you dig in the ground, you often see brown worms looking like bits of rusty wire. This is the wireworm, which feeds on the roots of plants for a year or more before becoming a beetle. The beetle is known as the click beetle or snapping beetle, because when it is placed on its back it springs into the air with a snap and comes down right side up.

Wireworms are often troublesome in vineyards planted on land where hay or grain has previously been grown. When they get into the vineyard the only way is to dig them out from around the roots. They do not do very much damage except where they are very numerous. (California Experiment Station, Bulletin 192; Washington, 4.)

Weevils. These are small beetles with peculiar snouts. They are found in grain, peas, beans, and other seeds. The clicking noise of their jaws may be distinctly heard when the ear is placed near seeds among which they are at work. Grain may be freed from them by placing it in a box and making the cracks tight by pasting paper over them, then placing a saucer of carbon bisulphid on top, and leaving it for twenty-four hours. Use one pound of carbon bisulphid to one hundred bushels of grain. Carbon bisulphid is poisonous and easily catches fire if brought near a light. The weevil in peas and beans may be killed by heating sufficiently to kill the weevils without injuring the seeds.

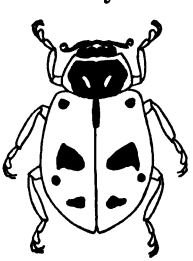

FIG. 111.—Ladybird, which eats scale insects and plant lice.

Plum curculio. In the East a beetle called the plum curculio or plum weevil damages the plums in much the same way as the codling moth damages the apple. (Utah Experiment Station, Bulletins 49, 65; New Mexico, 68; Washington, 38.)

Ladybirds. These beautiful little beetles are the gardener's best friends, for they feed upon the plant lice and help to keep them in check. The cottony cushion scale was a very serious pest in this state until the Australian ladybird was imported to keep it in check. It has proved a great success for this purpose.

If you look at plants which are covered with plant lice, you often see small, soft, wormlike insects, which you are apt to think are feeding on the plant. But if you watch carefully enough, you will see that they are

FIG. 112. — At the top a ladybird larva is seen eating a mealy bug half its size. Another mealy bug is seen a little lower down on the same twig. (Enlarged.)

feeding on the plant lice and destroying them. These are the larvas of ladybirds. They also feed on scale insects. After a time they become ladybirds and fly away to other plants.

Diabrotica and striped beetle. Figure 113 shows a beetle which is sometimes mistaken for a ladybird.

It is a great foe of the garden, feeding on various kinds of plants. It is called diabrotica. Another injurious beetle which is sometimes mistaken for a ladybird is the striped beetle found on melons and tomato vines. It is sometimes called squash bug. The only remedy for these beetles is to pick them off by hand, or go out early on cool mornings with a can containing a little coal oil, and shake them off the vines into the can.

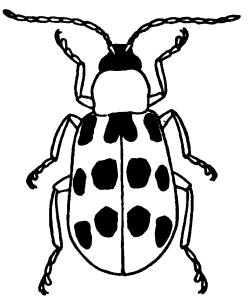

FIG. 113. — Diabrotica, which does much damage.

Graperoot worm. Figure 114 shows a leaf eaten by this beetle which sometimes does much damage in vineyards. It lays its eggs (late in June) on the stem of the vine near the ground. The worms (larvas) soon hatch out and enter the ground, where they feed on the roots. They pass the winter underground. In the spring they become pupas and soon come out of the ground as beetles. During May and June the

FIG. 114. — Leaf eaten by graperoot worm.

beetles begin to feed on the leaves. Then they lay eggs and disappear. Deep cultivation about the vine may destroy many of the pupas. The beetles may be killed by a strong arsenical spray, or caught by jarring them from the vine into a cage. (California Experiment Station, Bulletin 195.)

ANTS AND BEES

Ants and bees are the most wonderful insects we know. In a hive of bees or a nest of ants all work together for each other's good in a way which we cannot but wonder at.

They have queens which they guard with the greatest care, and workers which do all kinds of work. They divide up the labor of the nest or hive, each worker doing its share and attending to its own work.

Ants. Some of the ants have special police or soldiers; these are larger than the workers and have powerful jaws for fighting. Some ants capture the young of other kinds and bring them up as slaves. Some kinds plant gardens and harvest crops. Others are hunters and, marching together in great numbers, may even kill and devour animals as large as cows.

Many kinds of ants take care of plant lice, and by stroking them make them give out drops of a sweet liquid. This is known as milking, and the plant lice are sometimes called "ant cows." The ants protect them and take care of them much as we do of our domestic animals. In Central America the acacia tree produces a sweet substance which serves for food and

hollow thorns which serve for dwellings of an ant. This ant is said to protect the tree against another kind of ant which tries to cut out pieces of the leaves and carry them to its nest.

Ants are always friendly with others of the same nest, but if another kind of ant is dropped into the nest, it is at once killed. They seem to recognize each other by the sense of smell.

Inside the nest the young are very carefully looked after. At night they are carried to the warmest part of the nest, and the outer opening of the nest is protected. In the morning they are carried to the outer chambers, or even placed in the sun. A change of weather quickly sets the ants to work carrying the young into the nest.

Bees. Inside the door of a beehive certain bees stand guard. If any insect which has no business there tries to get in, they raise an alarm. Then the other bees come and sting it to death. Sometimes a whole army of bees of some other sort comes to rob the hive, and then there is a fierce battle which may last for hours.

When the bees come in with pollen and honey, they go through a sort of dance before they unload it into a cell of the comb. Some are at work all the time building the comb, others carry them the wax to build with, while still others make the wax. Some of them go about cleaning up the hive, while others ventilate it by standing at the door and forcing in fresh air by

fanning with their wings. And then there are the nurses who feed the babies and take care of them. The queen goes about laying eggs, attended always by a guard of honor who go with her, keeping their heads always toward her as she moves about. Then there are the battles between the old and new queens, which go on amid the wildest excitement, with all the bees crowding around to see. And the greatest event of all is when a swarm leaves the hive, and the bees are all excited to such a pitch that they seem beside themselves. (See page 406; read also what is said about bees in Kellogg's " Insect Stories.")

In order to see some of these things we may make beehives or ant nests with walls of glass, through which we may watch them at work. The glass must be covered to keep out the light. A small beehive of this sort can be made by anyone, using a box about eighteen inches square and four inches deep, and replacing the top and sides by panes of glass. It should stand upright. This may be covered with cardboard or cloth to keep out the light. The hive may be kept indoors, but a small opening must be left to the outside (under a window, for example) for the bees to go in and out. Such a hive succeeds even in a city. (See Hodge's " Nature Study and Life," Chapter 14.) Read what is said about bees on pages 406 to 410.

For ants the best plan is to take two pieces of glass two inches square (or larger), and fasten them together by rubber bands and put pieces of cardboard between them at the edges, so as to hold them a little apart. If they are too far apart, the ants will not like it, but there must be space

enough between them for the ants to move about. Place the glass on a piece of wood in an agateware pan, and pour in some water. This is to keep the air moist and prevent the ants from escaping. Now dig up an ant nest and place some of the ants, together with the young (which look like white grubs), on the glass in the pan. Cover the pan with a piece of glass, and over this put a piece of cardboard to keep out the light.

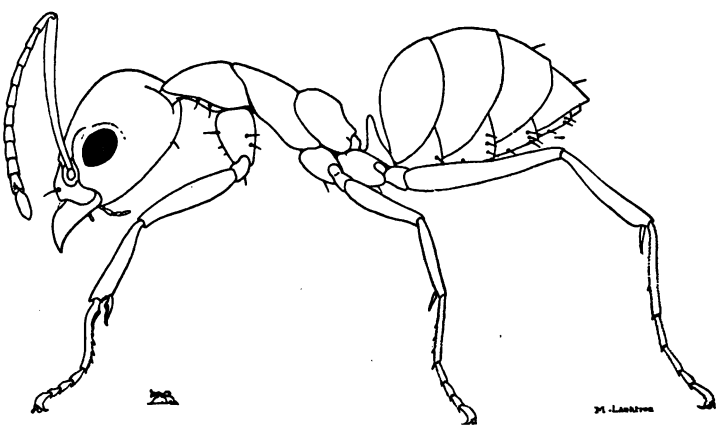

FIG. 115.—Argentine ant, which does much damage, and which is spreading on the Pacific slope. (The smaller figure is a little less than natural size.)

Better still, get a sheet of transparent lemon-colored celluloid, lay it over the glass cover of the pan, and on it place another glass cover. The ants behave in the yellow light just as if they were in darkness, and can be watched without taking off the cover.

The ants should be fed with honey and bits of meat, which may be placed on the glass strips.

A very injurious ant which may spread rapidly on the Pacific Coast is the Argentine ant (figure 115).

DRAGON FLIES

Everywhere in the brooks and ponds you find the curious larvas of dragon flies and caddice flies, which are very interesting to watch if brought home and placed in a small aquarium. The dragon fly larvas help to destroy the mosquitoes, gnats, and flies. They are so well described in the insect books that nothing more need be said about them here.

Every schoolroom should have an aquarium, even though it be only a fruit jar or tumbler. Directions for making aquaria are found in Hodge's "Nature Study and Life," Chapter 24.

GRASSHOPPERS

A great amount of damage is done each year by grasshoppers. The eggs are laid in the ground in late summer or fall, and hatch the following spring. The young grasshopper is without wings at first, but acquires them as it grows. After getting their wings the grasshoppers sometimes fly in enormous numbers. Many farmers find turkeys the best protection against the grasshopper; others use poisoned bait (bran, molasses, and arsenic) or spray or put poison all around the edge of the field. A large shallow pan (about six by three feet) containing crude oil, known as a "hopper dozer," has been used with success. It is dragged

across the field. A light pole running before it causes the grasshoppers to jump, and an upright screen behind it prevents them from jumping over it. Even those which at once jump out of the pan usually get enough of the crude oil on them to kill them. Burn-

FIG. 116. — Grasshopper. (Enlarged.)

ing and plowing the places where they breed and feed helps greatly to keep them in check. (California Experiment Station, Bulletins 142, 170, and 192; Idaho, 41; Nevada, 57; New Mexico, 63, 68.)

A wingless grasshopper known as a "cricket" has done much damage in the Northwest. (Idaho Experiment Station, Bulletin 41; Nevada, 56; Wyoming, 32.)

MOSQUITOES AND FLIES

Mosquitoes and flies have only two wings, while the moths and beetles, already studied, have four wings. Both mosquitoes and flies suck up their food through a part of the mouth which is called a sucker. You can easily see what this looks like when a house fly feeds on a piece of sugar, or when a mosquito bites you.

The eggs hatch into larvas, which after a time turn into pupas, out of which comes the mosquito or fly.

MOSQUITOES

Some mosquitoes carry malaria. One may live in a swamp full of malaria, but if he is not bitten by mosquitoes, he will not catch the disease.

FIG. 117. — A mosquito which carries malaria.

Mosquitoes lay their eggs in water (both fresh and salt) or in mud, and the eggs hatch out into "wrigglers," which come to the surface every little while to breathe. A little kerosene on the surface of the water soon kills them all. Cisterns may be treated in this way,

and if the water is drawn off from below, it will not taste of oil. A roof over the cistern helps to prevent mosquitoes from breeding, because the small plants on which they feed cannot grow in the darkness; oil is not always needed in such cases.

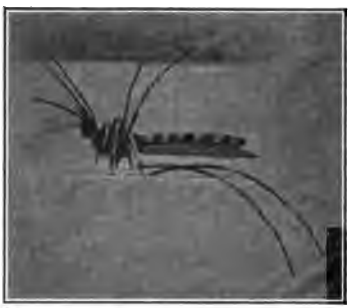

FIG. 118. — A mosquito which does not carry malaria.

By putting oil on the surface of all standing water, the mosquitoes can be entirely gotten rid of. Swamps should be drained wherever possible.

Not all kinds of mosquitoes carry malaria. Figures 117 and 118 show the differences between one which carries malaria and another which does not. The figure shows them resting on the ceiling. Notice that the one which carries malaria stands with its body perpendicular to the ceiling as if ready to bore into it, while the other has its body horizontal. The former seems to have three beaks, though really only one, and looks much more dangerous than the latter, which shows only one.

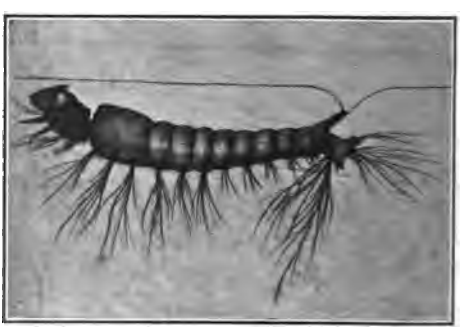

FIG. 119. — Wriggler (larva) of a mosquito which carries malaria.

These two kinds of mosquitoes look much more nearly alike when they rest on a vertical wall. The principal difference is that the one which carries malaria holds its body straight, while the other looks somewhat humpbacked.

Mosquitoes with no spots on the wings carry no malaria. Not all kinds with spotted wings carry malaria, but only those which seem to have three beaks, as shown in the figure. Of these, only those which actually bite are of any importance.

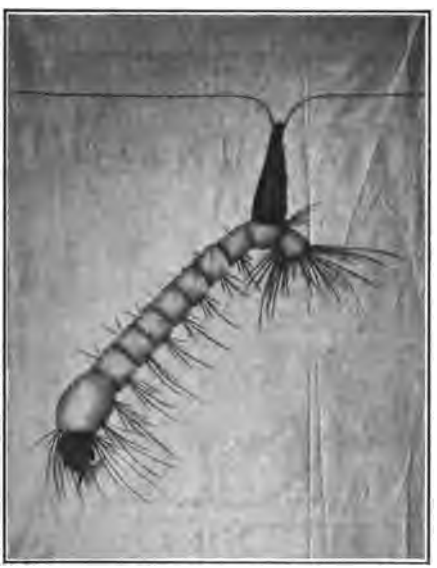

FIG. 120. — Wriggler (larva) of a mosquito which does not carry malaria.

If you find any of the wrigglers, bring them indoors and place them in a tumbler filled with water. Tie a piece of cloth over the top, so that when they become mosquitoes they cannot fly away. If they are of different kinds, put them in separate tumblers. Figures 119 and 120 show two different sorts. The one shown in figure 119 becomes a mosquito which carries malaria, as shown in figure 117. The one shown in figure 120 becomes a mosquito like the one seen in figure 118, which carries no malaria. The first one acts as though it were lighter than the water; it lies close to the surface and seems to have difficulty in moving downward, while the

second hangs from the surface, and moves downward more easily than upward, as though it were heavier than the water.

Notice how often the wrigglers come to the surface to breathe. Notice also the curious breathing organ which looks like a sort of tail. You will be able to see how the wriggler sheds its skin two or three times as it grows larger and finally comes to look as if it were coiled up at one end. It is then a pupa (figure 121). After remaining for some days in this condition, the skin splits and the winged mosquito comes out.

FIG. 121. — Pupa of mosquito.

Place a little kerosene or crude oil on the top of the water containing the wrigglers; how long do they live? Find out whether tadpoles or fish will eat them. (California Experiment Station, Bulletin 178, 1906.)

FLIES

House flies breed in stables or in places where there is garbage, and the only way to get rid of them is to keep such places clean. From their breeding places they come into the house, often carrying disease germs which they scatter wherever they walk. Read what is said about flies on page 262 (figure 155).

As the fruit fly chooses a less disagreeable place to breed, we will study it instead of the house fly. A tumbler half full of fruit juice on which a piece of blotting paper floats

will serve. We place in it some of the brown fruit flies which may be caught wherever there is decaying fruit, and we lay a piece of cardboard over the top. We can then see how they lay their eggs on the blotting paper. In a few days the eggs hatch, and the larvas (called maggots or worms) come out. They will probably crawl up the sides of the tumbler and go into a resting condition (pupa), from which they come out as winged flies.

CHAPTER XVI

FOES AND FRIENDS OF THE PLANT (Continued)

SUCKING INSECTS (BUGS)

THE name "bug" is properly given only to insects which have beaks with which to suck up their food. Plant lice and scale insects are bugs. Mosquitoes and flies are not bugs, because their sucking organs are very different from the simple beak of the bugs.

Sucking insects may be kept in check by sprays which kill them by touching them. Sprays such as arsenate of lead or Paris green, which kill only when *eaten* by the insect, have no effect on the *sucking* insects, because the arsenate of lead stays on the *out*side of the leaf, while the bug takes its food from the *in*side by sucking up the juices (see page 183).

PLANT LICE OR APHIDS

These are the very small green bugs so common on all sorts of plants, in doors and out. The tips of rose branches and the leaves of cabbage and mustard are often covered with them. They suck the juices from the young and tender parts of the plant and may do it great harm.

If you find many plant lice on a plant, you are almost

sure to see ants running up and down the stem. The ants are very fond of a sweet juice which the plant lice produce, and may sometimes be seen stroking them to make them produce more of it. This is sometimes spoken of as "milking," and the plant lice are often called "ant cows."

The eggs hatch out into plant lice like the parent, only smaller. These small plant lice grow rapidly and soon produce others like themselves. There may be several broods in a season.

In fact, if we started with but a single rose aphis at the beginning of a season and all that are produced should live, their weight at the end of the season would be equal to that of all the people in the world taken together.

A curious fact is that after a number of broods without wings, a brood with wings makes its appearance. This allows the insect to spread to other places.

Hop aphis. These seem to pass the winter in the hop yards, and appear in the spring as wingless forms on the pollen-bearing vines. Afterward winged forms appear. They sometimes do a great deal of damage to the vines. They may be completely controlled by sprays of kerosene emulsion and tobacco decoction or of whale-oil soap and quassia extract. (California Experiment Station, Bulletin 160, 1904.)

Grain aphis. In moist warm spring seasons the grain crops are sometimes greatly injured by the green grain aphis. No practical way has thus far been found of reaching and destroying it.

Plum aphis. In some seasons plum trees are overrun and their leaves are considerably injured by the bluish green plum aphis. It is easily controlled by spraying.

Cabbage aphis. This sometimes injures young plants seriously, and later infests the cabbage heads, making them unpleasant to handle. It is also found on wild mustard and wild radish; these weeds should therefore be kept down as much as possible. Sometimes it destroys the crop of mustard seed.

Plants may be sprayed in the seed bed and dipped into a soap or kerosene mixture, just before setting them out in the field. Plants may be sprayed in the field with petroleum distillate, about half as strong as for scale insects. (New Mexico Experiment Station, Bulletin 68; Utah, 65.)

FIG. 122. — At the left an apple branch attacked by aphis. It bears smaller apples and more of them. Ordinary branch at the right.

Melon aphis. This breeds on pepper cress and alfalfa. Near melon fields alfalfa should be cropped close, and pepper cress should be destroyed. (Arizona Experiment Station, Bulletin 47; New Mexico, 63, 68.)

Apple-leaf aphis. There are two kinds of aphis on the apple leaf, one of which causes what is known as "little

apples." An unusual abundance of fruit sets, but does not grow to full size (figure 122). Spraying at the right time is the best remedy. (Idaho Experiment Station, Bulletin 40; Oregon, 38.)

Woolly aphis. This attacks bark, roots, and stems. The injured places on the stems have a marked woolly appearance. In the early spring these may be touched with a swab dipped in gasoline, and if this be done early enough and often enough, it will check the aphis. The attacks on the root may be checked by putting lime around the roots. (Oregon Experiment Station, Bulletin 38; New Mexico, 68; Utah, 55, 65; Washington, 65.)

Phylloxera. The phylloxera is a very small insect (less than the size of a pin head) which attacks the roots of grapevines. It usually kills the European grapevine, which is the one mostly planted in California. Spots in the vineyard attacked by phylloxera may be known by the low growth of the vines and may show in the center some dead vines; outside these, vines which make little growth and produce no grapes; outside these, vines which do not make the usual growth, but may bear more than the usual amount of grapes; and outside all these, healthy vines which will become affected in course of time, if the spread of the insect is not stopped.

Various ways of checking the insect have been tried; such as flooding the vineyard for a time and putting carbon bisulphid in the soil. These are giving way to the use of resistant roots. These are roots of American grapes which

are but little injured by phylloxera and on which the European vines can be grafted. Riparia Gloire de Montpellier and Riparia Grande Glabre are among the best of these, but in dry places Rupestris should be planted. In selecting resistant roots you should take great care to get a sort which is adapted to your particular soil and which will be the right sort of stock for the particular European variety you wish to grow. The cuttings of the European varieties should be freed from phylloxera eggs, when brought into a region which is free from phylloxera. This may be done by putting the cuttings into a box or barrel, pasting paper over the cracks, and placing a saucer full of carbon bisulphid on top of them and closing with a tight-fitting cover. In an hour and a half, or in some cases a less time, the cuttings may be taken out. (Carbon bisulphid is poisonous and easily catches fire if brought near a light.)

In very sandy soils the phylloxera does little harm, but in clayey soil the damage is very great. By means of its beak the insect sucks out the juices of the root. The roots become covered with swellings, and on the larger roots large spots of decay form. In a short time the root dies below the injured place. In midsummer the insects occasionally become winged and come out of the ground. They may fly for short distances, or be blown longer distances by the wind. (California Experiment Station, Bulletin 192; Idaho, 46.)

White fly. This is a very serious pest to oranges and lemons in the East, and has recently been found in California. The eggs are laid on the trees, and the young, when first hatched, look very much like young scale insects. After wandering about for a few hours they fasten themselves by their mouth parts to the leaf and secrete wax, which soon fills the space between the leaf and the body of the insect. There are several broods in the course of the season. Its

snow-white color makes it easy to recognize. The young insects may be known by the fact that they are smaller than any similar scale insect and confine themselves to the underside of the leaf.

The best way to prevent it from spreading is to remove all the infested leaves and burn them at once. When it once gets in, it must be dealt with like any scale insect. (California Experiment Station, Circular 30.)

SCALE INSECTS

The scale insects (figures 123 and 124) are not larger than plant lice and, like them, feed by sucking the juices of the plant through their beaks.

Some are covered with a shell of wax, like the San José and oyster-shell scale. Some have a waxy covering, but no true shell. Others have no waxy covering and are called naked scales, such as the brown scale of the apricot and the black scale of the olive.

The males have wings, but no mouth parts. The females have mouth parts, but no wings. The females of many kinds lose their legs early in life and remain motionless thereafter.

Scale insects may be entirely controlled by sprays, which should be applied with considerable force. (California Experiment Station, Bulletin 166.)

San José scale. The appearance of this common and injurious scale is familiar to every one. The insects pass the winter in a half-grown condition. In the spring they grow

very rapidly, and produce young which crawl about for twelve to thirty-six hours, and then fix themselves to the branches of orchard trees (apples, pears, and many others) and secrete a shell of wax which completely covers them. They grow rapidly, and in about a month produce others like themselves. There are several broods in a year. Each female lays a large

FIG. 123. — A greenhouse scale (hemispherical scale) on a leaf. (Enlarged.)

number of eggs, which lie hidden beneath the scale of wax with which she covers herself.

The most satisfactory spray for this scale is the lime-sulphur spray, which is described on page 413. (California Experiment Station, Bulletin 166; Idaho, 31; New Mexico, 68; Oregon, 38; Utah, 65; Washington, 56.)

The cottony cushion scale. This scale at one time did a great deal of damage, but is now kept in check by the Australian ladybird (Vedalia), imported for the purpose from Australia.

Brown apricot scale. This does more damage upon prune than upon apricot trees. The lime-sulphur mixture is not satisfactory for this scale, but it may be controlled by using the resin compound described on page 412. (California Experiment Station, Bulletin 16, 1905.)

Red scale. The red scale of the orange, which does great damage in Florida and other places where oranges are grown, has now spread all over California.

Scale of the palm. This is described in Bulletin 56 of the Arizona Experiment Station.

Parasites of scale insects. By keeping leaves covered with scale insects in tumblers, we shall be able to see the tiny wasps, not much bigger than a pin head, which are parasites on the scale insects. They lay their eggs in the scale insects, and the young wasps feed on their bodies. After a time they come out as tiny winged wasps. The tumblers should be covered with cloth to prevent them from escaping.

FIG. 124. — Black scale on lemon. (Enlarged.)

THE VINE HOPPER

This is a small insect, not more than a tenth of an inch long, of a pale yellow color, with irregular red markings. They are usually found on the underside of the leaves.

The insects pass the winter feeding on various plants, and if the weather is severe, they are largely killed off. They lay eggs during the spring and throughout

FIG. 125. — Vine hopper; the empty skin out of which it has just crept (seen on the left) is smaller than the insect. (Enlarged.)

the season. They feed on the leaf by sucking its juices, and thus produce white spots; the leaves often turn yellow and fall off. Only when there are a great many of them do they do much damage. A great part of them can be caught by means of a hopper cage (described in Bulletin 192, mentioned below). Spraying is also useful. (California Experiment Station, Bulletins 116 and 192, 1897, 1907.)

FRUIT THRIPS

This very tiny insect, which is only about half as large as a plant louse, spends eleven months of the year underground. It comes out when the fruit trees begin to blossom and feeds upon the flower buds. It attacks the inside of flower buds and sucks out the juices so that they do not open. It damages especially the pears and prunes. No good remedy is known.

A different sort of thrips attacks onions and beans,

eating the leaves. It could perhaps be checked by spraying.

MITES

These are very tiny creatures which have eight legs, while the true insects have only six.

Erinose. When the leaves of your grapevines look very uneven and seem to be covered with little swellings, while the under side gets woolly, your vines are attacked by a small mite which causes the disease called erinose. It does not do much damage, and the sulphuring which the vines are given to check the oïdium or mildew checks also the erinose. (California Experiment Station, Bulletins 136 and 192.)

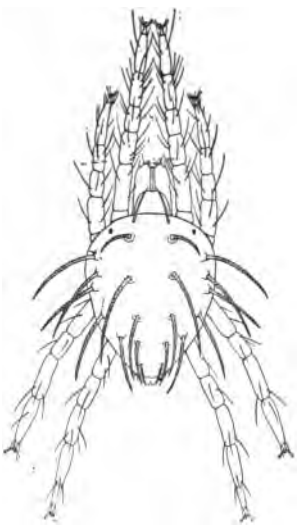

FIG. 126. — Red spider of orange in feeding position, showing how it takes hold with its four front feet and pulls, in order to force its beak into the leaf or fruit. (Enlarged.)

Red spider. The tiny red spider (figure 126) of citrus and other fruit trees causes the dropping of fruit (but not the spotting), and also injures the leaves. It feeds on the leaf by sucking out the soft fluid parts through the beak, thus causing white spots on the leaf. It lays its eggs on the leaves and also on the fruit (figure 127). Ladybirds and other insects feed upon it,

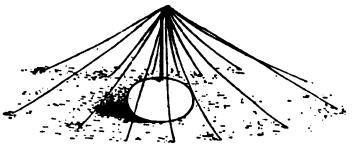

FIG. 127. — Egg of red spider of the orange. It is held by a series of guy ropes. (Much enlarged.)

but do not keep it in check. The best remedy is sulphur, used as a powder or as a spray. The red spider of the almond and other fruit trees may also be treated in this way. (California Experiment Station, Bulletins 145 and 154; Oregon, 38; Utah, 65.)

SPIDERS

Nothing is more interesting than the study of spiders and their habits. These are so well described in the insect books that nothing need be said of them here. Being insect-eaters, they are mostly useful.

CENTIPEDS

One of the centipeds which sometimes damage asparagus is shown in figure 128. The bite of our common centiped is often painful.

FIG. 128. — Centiped, which damages asparagus. (Enlarged.)

WHERE TO LOOK FOR INSECTS

In summer. All the insects mentioned above are in their active condition in summer, and may be found in the places described. The leaves of all cultivated plants should be examined. A cheap magnifying glass is useful for this purpose. A great variety of insects may be found by making a small net of cheese cloth and sweeping it over the grass. An inverted umbrella placed beneath a bush which is then shaken or beaten will yield many kinds. Others will be found by looking underneath dead bark, or by turning over stones or boards lying on the ground. Do not forget to look in the streams and ponds for water insects. Bring them home in a bottle and put them in a large tumbler of water, together with some of the green scum or other green plants growing in the water. Change the water as often as necessary. These insects are described in any book on insects.

In winter. Many insects remain active in winter and may easily be studied. Such are the potato worm in potatoes, the vine hopper, plant lice, scale insects, and many others. Others may be found in the egg stage (as the eggs of red spider on leaves) or in the cocoon stage (as the codling moth cocoons). Many others pass the winter in the ground, as the corn worm, cutworm, thrips, woolly aphis, and phylloxera. The harmful grasshoppers are all in the ground in the egg stage at this season.

How to find the names of insects. Insects which are found injuring cultivated plants will be named if they are sent to the Entomological Department of the Experiment Station in your state. Each kind should be placed in a box by itself (a pill box is sufficient) and a number placed on the box. It is well to prepare two boxes of each kind, sending

one and keeping the other until the name is received. A very good way to kill the insects is to make pin holes in each pill box and then place them all in a fruit jar, drop in a little gasoline, and then close the jar tightly and leave it overnight.

A bulletin on butterflies may be obtained for ten cents from the Superintendent of Agricultural University Extension, University of California, Berkeley, Cal.

Directions for collecting and preserving insects are given in Hodge's "Nature Study and Life," Chapter 4. In place of the poison there mentioned, it is safer to use gasoline for killing the insects.

FIG. 129. — Lamp-chimney breeding cages placed over plants growing in pots. The top may be covered with cloth or strips of glass.

Breeding cages. A large tumbler will serve most purposes. It may be turned upside down or placed upright with a piece of cloth tied over the top. A lamp chimney may also be used in this way, or a wooden box may be covered with cloth or mosquito netting. Holes may be made

in a covered box of wood or pasteboard and the necks of bottles fitted into these so that the body of the bottle projects outside the box. If such worms as army or cut worms are placed in the box, together with the leaves on which they feed, they will, when they have finished feeding, crawl into these bottles, attracted by the light, and there change into moths.

OTHER ENEMIES

Root galls caused by nematodes. Very small worms called nematodes cause swellings on many roots. On the grape roots these look like the swellings caused by phylloxera, but they are somewhat larger and firmer. No remedy is known, but it is possible that roots which resist their attacks may yet be found.

The dying out of many plants, such as violets, after being grown a long time in the same place, is often caused by nematodes. The remedy is rotation of crops. For example, if beets are badly attacked by nematodes, grain should be grown for a year or two in place of beets, so as to starve the nematodes out. (California Experiment Station, Bulletin 192.)

Slugs and snails. These may be trapped by putting cabbage leaves on the ground with the hollow side down, so as to leave a little space between the leaf and the ground, in which the snails gather during the night. By going out early in the morning, you can catch and destroy them. Choice plants may be protected by an upright strip of zinc sunk edgewise into the soil so as to

stand up two or three inches above it. The snails are not able to get over the sharp edge, and the plant is thus protected.

Field mice and gophers. These feed upon the roots and seeds of plants, and often cause enormous injury on account of the rapid increase in their numbers. Poison is the best remedy against them. For the gopher we place poisoned baits of carrot, turnip, or raisin in their burrows. There are also good traps.

Field mice are killed by means of poisoned grain or ground alfalfa. The alfalfa is best, because it is not eaten by the birds.

HELPFUL INSECTS AND ANIMALS

There are many insects which help the farmer by destroying other insects. Not only ladybirds (page 196), but tiger beetles, lion beetles, and some kinds of hornets and flies attack and kill insects which damage plants. Spiders also live on insects.

Whenever you try to breed insects, you are sure to find that very often in place of the moth or butterfly which you are expecting you get nothing but a lot of small "flies." These have laid their eggs on or in the caterpillar or worm, and in time they hatch and feed upon it. Then they come out, become pupas, and in a short time turn into winged flies (which may be true flies

with two wings, or ichneumon wasps with four wings). (Hodge's "Nature Study and Life," Chapter 14.)

Toads. Every one who has a garden knows that the toad is the best friend he has in helping to keep insects in check. If you wish to see how many insects it consumes, put it into a box with some moist earth, and after a day or so bring in all the insects you can find (of all sorts) and put them where the toad can get at them.

Frogs and related animals also live largely on insects. (Hodge's "Nature Study and Life," Chapters 16 and 17.)

Birds. Many birds help to keep insects in check by feeding on them. This is a help to the farmer even when the insects eaten are not attacking crops, because almost any insect may, under favorable conditions, become a pest, and it is well to have all of them kept in check (except of course the helpful ones mentioned above).

A few of these birds also eat fruit and grain, and so may do as much harm as good. But it is well to encourage and protect the birds as much as we can. Nesting places made of boxes or old tin cans placed on trees or posts near the house will help to make the home grounds more pleasant by attracting the birds. (Hodge's "Nature Study and Life," Chapters 18 to 21.)

Hawks and owls are almost wholly beneficial, because they kill gophers, field mice, and similar pests of the

farmer, and rarely hurt poultry. Instead of being killed, they should be protected.

Snakes. Few snakes are poisonous, and these can easily be known in each locality. Most snakes, such as chicken snakes, whip snakes, and gopher snakes of various kinds, are wholly beneficial, as they live on field mice, gophers, and other small pests.

Earthworms. Earthworms help the roots by cultivating the soil and making it loose (see page 68).

CHAPTER XVII[1]

DISEASES OF PLANTS

In our country alone the loss from plant diseases amounts to many millions of dollars each year. Nearly all of this can be avoided. We must first find out what causes the disease. We can then usually find some way to check it.

This loss is mostly caused by tiny plants called *fungi*. If you wish to see what they are like, put a bit of moldy bread on a piece of wood in a saucer and cover it with a tumbler. Pour a little water into the saucer to keep the air moist. Soon a white growth is seen. If you look closely at it, you will see that it looks like a mass of threads. You can see that the threads have branches (figure 130). Most fungi are such masses of branching threads. Even a bit of toadstool looks under the microscope like a mass of such threads.

In place of seeds the fungi have tiny spores, so small that they cannot be seen by the naked eye. Each one of the little black bodies shown in figure 130, which are

[1] The teacher is especially advised to take up only one or two typical forms, which can easily be obtained in his locality, for illustration.

seen after the mold has grown for a week or so, contains hundreds of these spores. Each spore can grow

FIG. 130. — Mold growing on a piece of bread, showing the young spore cases (white dots) and the old ones (black dots). (Enlarged.)

like a seed and produce the fungus. You can see the spores of a toadstool very easily by cutting off the top and placing it right side up on a piece of paper. If the

spores are of light color, they will show best on a piece of dark paper.

Notice how easy it is to blow the spores away. You can see how easily the spores of mold are carried everywhere by the wind. Spores float a long time in the air, and it is very hard to get rid of them. We protect our jams and jellies from mold by pouring a layer of melted paraffin over the top. And we must clean out the bread box with soap and water very often to get rid of mold spores. A little formalin is still better than soap and water, but it must be rinsed away afterwards, as it is poisonous.

The fungi are not green and cannot make their food from air and water as green plants do (page 73). They take their food from living plants or animals or from dead animal or vegetable matter.

Some of them grow only on dead matter (either animal or vegetable), and they may do good by helping to get rid of it. Others attack living plants or animals. These cause disease, and some of them do a great deal of harm. The diseases of animals are largely due to minute fungi called bacteria, which we will study farther on. Let us now look at some fungi which cause diseases of plants.

MOLDS AND RELATED PLANTS

Every one has seen the blue or green spots on oranges and lemons which are made by mold (figure 131).

Until recently there has been a great deal of loss every year from this cause. Now we have found out how to prevent it.

If you wish to see how this is done, place a very moldy orange or lemon in a cup and cover it with water.

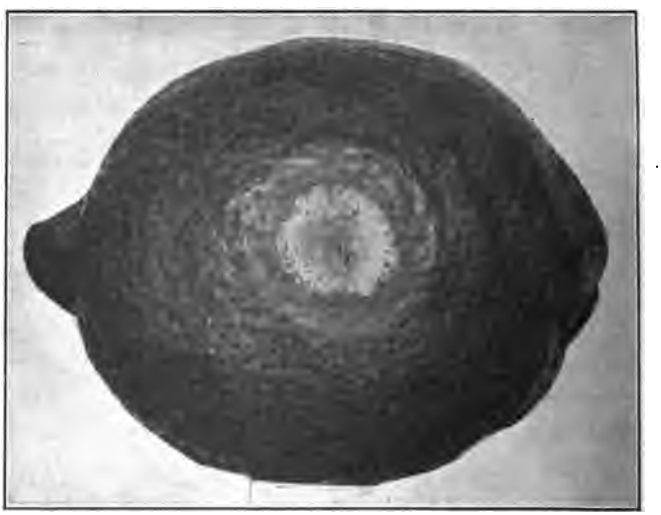

FIG. 131. — Blue mold on lemon.

You will then probably see on the top of the water something which looks like dust; this is made up of very fine particles, each one of which is a spore. Each one of these spores will grow and make a mold spot if it gets a chance.

Take a sound lemon or small orange and mark it with some sort of design (such as a cross or your initials)

by scratching the skin with a pin. Now touch the surface of the water or the moldy spot on the fruit with your finger, so as to get some of the spores on it, and rub it all over the surface, especially over the scratches. Place the fruit in a tumbler or glass jar, with a little water at the bottom. Do not allow the fruit to touch the water. Cover the jar or tumbler, so as to keep the air moist inside. Let it stand for two or three weeks. Does the mold always start where the skin is broken?

FIG. 132. — The blue mold has not spread from the moldy lemon to the others in the box, because they have been carefully handled and their skins are not broken.

It is perfectly clear from this experiment that the growth of mold can be prevented if care is taken not to break

the skin. This is just what the growers and packers have found, and this knowledge has been worth many thousands of dollars each year.

Brown rot of the lemon. Another disease which produces spots on lemons is the brown rot. This is able to penetrate the skin even where it is not bruised or broken. If in the experiment just described the growth starts where the skin is not broken, it is probable that we have the brown rot. But the wound through which

FIG. 133. — The brown rot is spreading from the lemon on the right to the lemon on the left, in spite of the fact that its skin has not been bruised or injured in any way.

the blue mold gains entrance may be invisible to the naked eye.

A lemon with brown rot will soon affect all the lemons in the box or pile in which it is placed (figure 133).

But a lemon with *blue* mold cannot infect the lemons around it, unless their skins are bruised or broken (figure 132).

The brown rot also differs from blue mold in producing a peculiar odor which attracts swarms of small flies.

The soil in the orchards is in many cases filled with the spores of brown rot, but if the fruit can be kept from touching the soil (or from being splashed by water from the soil), no rot develops. In some cases a "cover crop" of vetch may protect the fruit by covering the soil closely; in other cases the lowest branches of the tree may be pruned away.

But it often happens that some of the fruit has the brown rot on it, and the water of the washer in which the lemons are washed becomes infected. It is then necessary to add something to the wash water to kill the fungus. Formalin, bluestone, and permanganate of potash have been used for this purpose with entire success. (California Experiment Station, Bulletin 190, 1907.)

Place some lemons infected with brown rot in a pail of water and wash them thoroughly. Take them out and place some sound lemons in the water; allow them to stand overnight; in the morning take them out and put them aside; how many develop brown rot?

Take out a pint of this water and add to it a teaspoonful of formalin; put some sound lemons in it overnight;

take them out and put them aside; do any of these develop rot? Can you destroy the spores by boiling the water as well as by adding formalin? Place some sound lemons in a box, and lay an infected lemon on top of them. Does it infect any of the lemons except those it actually touches? This shows how important it is to sort out all infected lemons when packing the boxes.

Brown rot of stone fruits. This attacks apricots, plums, and peaches, causing the young fruit to turn brown and later on to shrivel and dry up on the tree. The fruit is then covered with a coat of the mold. It may be checked by spraying with Bordeaux mixture. (Oregon Experiment Station, Bulletin 57; Washington, 83.)

Potato and tomato blight. The fungus causing these diseases does not merely attack the surface, but penetrates into the plant. It causes the dreaded potato blight of the East and Europe, and has caused some trouble in this part of the country. It sometimes attacks tomatoes during wet weather, and is then called winter blight. It is important to know that it is different from the summer blight of the tomato (page 246), which is not affected by spraying.

The winter blight appears as dark spots on the leaves, stems, and fruit. Soon the whole vine becomes black and dead, with green spots remaining here and there, exactly as though the field had been struck by frost. The best remedy is spraying with Bordeaux mixture. (California Experiment Station, Bulletin 175; Washington, 46, 83; Wyoming, 71.)

A similar fungus, the downy mildew, has caused severe loss on the onion seed farms during wet weather.

Damping off. Whenever young plants grow closely

crowded, as in seed beds, they are apt in damp weather to "damp off." The cause is a fungus similar to the one just mentioned. When it attacks the plants they rot and turn black near the surface of the ground..

Keeping the plants dry, stirring the soil, letting in air and sunshine, help to keep it in check. Seed beds should be made of fresh soil free from the fungus. (California Experiment Station, Bulletin 175, 1906.)

POWDERY MILDEWS

A whitish appearance is often seen on leaves, especially those of roses (figure 134), lilacs, hops, peas, beans, peaches, apples, currants, cucumbers, and grapes. It is caused by the growth of fine white threads of fungi which are known as powdery mildews. They look a great deal like the molds and, like them, grow on the surface, not penetrating into the plant as some fungi do. For this reason it is easy to kill the mildews by spraying the surface of

FIG. 134. — Powdery mildew on rose leaf, causing a whitish appearance.

the plant. Dry sulphur seems to be best for this purpose (Bordeaux mixture is also used). Like most fungi, the mildews grow best in moist weather; when it is dry and hot, they cause no trouble.

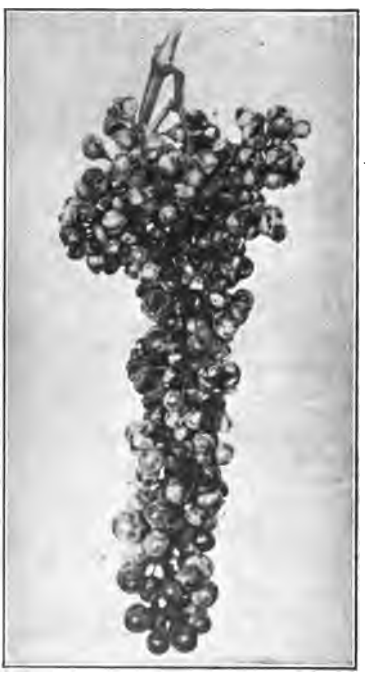

FIG. 135. — A bunch of grapes attacked by oïdium or powdery mildew.

If the leaves are well covered with the white fungus, we can often see (especially on lilac leaves) small black bodies scattered over the surface; these contain the spores. They may pass the winter on the fallen leaves or in the soil, and in the spring open and set the spores free. During the greater part of the season another kind of spore is produced on the leaf. Any of the spores which come in contact with the plant can then start a new growth of the fungus.

One of the worst mildews is that which attacks the grape (it is also called oïdium). The grape crop has been completely destroyed by this in some cases, but it is now controlled completely by dusting dry sulphur

over the leaves. (California Experiment Station, Bulletin 186; Idaho, 31, 39; Washington, 70, 83.)

FIG. 136. — Oïdium or powdery mildew on grapes, causing a whitish appearance.

SMUTS

The smut of corn forms on the ear and other parts of the plant large white masses which open and send out great clouds of black spores (figure 137). Formerly the grains of corn were treated with a germicide to prevent smut, but this does no good, because infection may take place on any very young part of the corn plant.

With the smuts of grain (black smuts of wheat, oats, barley, and rye, stinking smut of wheat) infection takes place only very soon after germination, and mainly from spores on the grains. Hence they can be prevented by treating the seed with bluestone or formalin. The seeds must be covered by the solution long enough to get thoroughly wet (wheat for a few moments; oats

FIG. 137. — Corn smut.

and barley, on account of their hulls, from eighteen to forty hours) and then dried before sowing.[1]

[1] Year Book of the U. S. Dept. Agriculture for 1894, article by Swingle, and for 1896, article by Carleton. California Experiment Station, Bulletin 181; Idaho, 53; Oregon, 63; Utah, 84; Washington, 83.

Like most other fungi, the smuts do the most damage in wet weather.

RUSTS

Every one who is familiar with grain as it grows in the field has seen the black or reddish spots on the stalks which are known as rust. The red spots are seen under the microscope to be masses of red spores which are called the *summer spores;* the same fungus which produces these spores also produces black spores which cause the black spots; these black spores are called *autumn spores.* They rest during the winter, and in the spring infect the barberry plant by means of the wind, producing little reddish cups on the leaves known as *cluster cups.* The spores produced in them are called cluster-cup spores. They in their turn infect the plants of grain on which the summer and autumn spores are again produced. If there are no barberry bushes near by, the summer spores may, in some cases at least, live through the winter and infect the grain in the spring.

FIG. 138. — Asparagus rust. (Natural size.)

It is probable that the rust of one

kind of grain as a rule cannot infect another kind of grain.

There are also other kinds of rusts which attack grain (such as the orange leaf-rust of wheat and rye and the crown rust of oats), which form their cluster cups on plants other than the barberry.

The yearly loss from grain rust in the United States is more than eighteen million dollars.

In threshing grain the red spores of rust gather in various parts of the machine and may sometimes be gathered up by the pint.

FIG. 139. — Rust on rose leaf.

Asparagus rust. Asparagus rust (figure 138), which has caused great damage in the past, has been found to disappear entirely, if the plants are dusted with dry sulphur while the dew is on them. If there is not sufficient dew on the plants to make the sulphur stick, they must be sprayed with whale-oil soap before using the

sulphur. (California Experiment Station, Bulletins 165, 172.)

Other rusts. Rusts are also common on stone fruits, almonds, blackberries, beets, alfalfa, carnations, chrysanthemums, hollyhocks, and roses (figure 139). They are not troublesome except in dry weather.

SHOT-HOLE FUNGI

Peach blight. The spores of the fungus germinate during the winter rains, and in a short time both the leaves and shoots of the peach tree (and later the young fruit) show numerous gummy spots or streaks which may be an inch in length. Many of the buds are killed outright. Small spots of dead tissue fall out of the leaf, causing the so-called shot-hole effect. Around the dead spots on the new wood, masses of gum are formed, especially in wet weather. The new growth in the spring is often killed completely, causing a total loss of the crop.

The disease may be entirely prevented by one spraying with Bordeaux mixture applied late in the fall; if possible, the trees should be pruned before spraying. Figure 140 shows how spraying checks the disease. (California Experiment Station, Bulletin 191.)

The same fungus also attacks the apricot and sometimes kills large branches. The most common effect is a scabbing of the fruit. Many of the buds are killed as on peaches, but the gumming of the twigs is not as

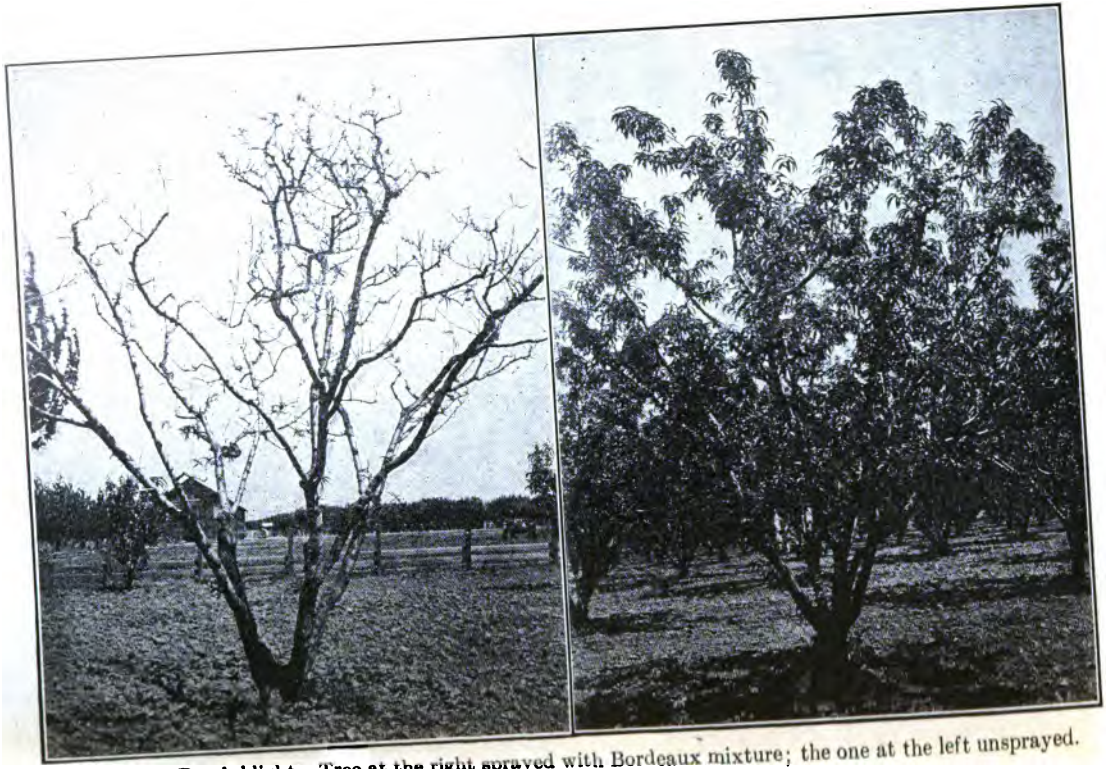

FIG. 140.—Peach blight. Tree at the right sprayed with Bordeaux mixture; the one at the left unsprayed.

bad. The leaves also show the shot-hole effect. On the almond the greatest effect is seen in the leaves, which develop shot-holes and fall from the tree.

Cherries, plums, and prunes are not so commonly affected.

Other kinds of shot-hole fungi exist, but have not caused serious trouble. (Utah Experiment Station, Bulletins 55, 65.)

FIG. 141.—Pear blight attacking flowers and twig.

BACTERIAL DISEASES

Pear blight. This very well-known disease begins by attacking young flower buds (figure 141), and spreads downward on the twigs, causing black streaks on the smaller branches. These streaks run down upon the larger branches to the trunk and finally kill the tree. The disease attacks not only pears, but also apples, quinces, and loquats. It is caused by bacteria, and it is believed that these are carried from tree

FIG. 142.—Pear blight entering trunk of tree through a small infested branch whose leaves are already dying.

to tree by bees and other insects which visit the flowers. The disease may enter through small branches such as the infected one shown in figure 142. The only remedy is to cut out and burn all diseased twigs, disinfecting all the tools used with a 5 per cent solution of carbolic acid. (Idaho Experiment Station, Bulletin 39; Utah, 65; Washington, 83.)

FIG. 143. — Walnut blight on leaves.

Walnut blight. This is also caused by bacteria. It makes black cankered spots on the young nuts and causes them to fall early or makes the kernel decay. In bad cases the twigs are also killed. (Oregon Experiment Station, Bulletin 92.)

FIG. 144. — Walnut blight on nuts.

Olive knot. This is due to bacteria which cause swellings or "knots" on the

trunks and branches (figure 145). It also attacks branches, twigs, and leaf-stalks. To check its spread, cut out and burn as in pear blight; also avoid wounding the trees and prune each tree a little at a time rather than all at once. Buds or cuttings should not be taken from infected orchards. (California Experiment Station, Bulletin 120.)

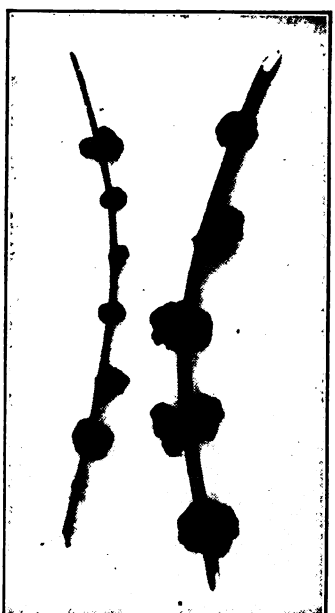

FIG. 145. — Olive knot.

The same disease attacks the oleander.

Crown gall. This disease, which is probably caused by bacteria, attacks woody plants near the surface of the ground. It causes swellings somewhat like those of the olive knot. It seems to enter the plant especially through wounds made in plowing or in transplanting. By preventing such wounds we help to keep it out. The galls may be removed from time to time. The bacteria seem to live in the soil, and are very hard to get rid of. (Arizona Experiment Station, Bulletin 33; New Mexico, 58; Utah, 55, 65; Washington, 83.)

OTHER DISEASES

Leaf curl. This disease is caused by a fungus which grows in the leaf and causes it to curl up; it is especially common on peach trees. It may be entirely prevented by the use of Bordeaux mixture in the spring before the buds swell.

FIG. 146. — Pear scab.

Leaf spot. Many kinds of fungi cause leaves to become spotted. They attack especially berries, celery, beets, and carnations. As a rule, they may be checked by spraying with Bordeaux mixture.

Wilt. This is caused by a fungus which grows in the water ducts of the plant, so that they are unable to carry enough water to the leaves. The whole plant gradually sickens, wilts, collapses on the ground, and dies.

Watermelons and tomatoes are attacked by this disease. When it attacks the tomato it is called summer blight (for winter blight, see page 234).

Spraying for this disease is useless. The seed bed should be made with soil free from the fungus. (California Experiment Station, Bulletin 175; Idaho, 31.)

Potatoes, sweet potatoes, and carnations are attacked by a similar fungus.

The wilt of squash and pumpkin is due to bacteria.

Scab of apple and pear. The well-known scab of fruit (figure 146) has caused great loss to pear growers and also affects apples. It can be checked by spraying. (Idaho Experiment Station, Bulletin 39; Utah, 49, 65; Washington, 64, 75, 83.)

Potato scab. This well-known disease, which causes much trouble, is best treated by dipping the seed potatoes in formalin. (Idaho Experiment Station, Bulletin 52; Washington, 83; Wyoming, 32.)

FIG. 147. — Toadstool fungus on cherry trees.

Split pit. This is seen principally in peaches. The pit splits and may become cracked into small pieces. A good deal of gum is also produced around the pit, and this may appear on the outside of the fruit. The cause is not known, but it does not seem to be due to a parasite.

Root rot. This is a decay of the roots and lower part of the trunk and may be caused by fungi entering from the soil or by fungi entering from wounds made by pruning and working their way downward. It attacks the apple, almond, and the stone fruits. Some of the toadstool fungi (figure 147) seem to be the cause of at least a part of this trouble. The best way of checking it is to avoid wounds, and to paint over wounds with tar to prevent the fungi from entering. (Washington Experiment Station, Bulletins 59, 83.)

FIG. 148. — Effect of beet blight; the beet is blackened inside in rings.

Gum disease of citrus trees. This disease shows itself on the trunk of the tree. Gum breaks out through the bark. The cambium (see page 87) is injured and the tree may die. The root is not usually affected. The cause is usually found to be some unfavorable soil condition, especially irregularity in water supply.

Beet blight or curly top. A peculiar disease of the sugar beet; the leaves are stunted and curl in a peculiar way. The roots become blackened in rings inside and the whole crop is sometimes lost. The cause is not known.

Club foot. This disease is found on the roots of cabbages, turnips, and radishes, producing large swellings or tumors. (Washington Experiment Station, Bulletin 83.)

Sour sap of stone fruits. Fruit trees sometimes die quite suddenly while in full leaf, commonly in the early spring.

Apricots and prunes are most commonly affected. The trouble seems to be due to weather conditions, especially to warm weather in early spring followed by cold wet weather. The sudden checking of the activity of the tree seems to produce a fermentation and souring of the sap. The trouble is not caused by fungi.

FIG. 149. — Club foot of turnip.

Puffy oranges. This affects especially the navel orange in certain seasons. The skin is puffy and spongy. The pulp is worthless. The cause is not known, but it is not due to a fungus.

Die back. Trees often begin to die from the top. The smaller branches are usually affected first and then the larger ones. Fruit and nut trees are often affected in this way. The trouble is sometimes due to crown gall (page 245), root rot (page 248), or the attacks of insects or gophers. But in other cases it is caused by the roots meeting hardpan or alkali or some other unfavorable condition. Unusually warm weather in fall or winter may also cause it.

Chlorosis. White or pale spots on the leaves, sometimes extending over the whole leaf, are caused by a variety of unfavorable soil conditions, including alkali and excess of lime. They are also produced by other causes.

Many other diseases, such as the " Anaheim disease " and root rot of grapes, cannot be described for lack of space.

Directions for making sprays are given on page 412.

CHAPTER XVIII

BACTERIA

It used to be thought that everything decays naturally sooner or later, and that this cannot be helped. But we now know that decay is caused by very small plants (called bacteria), and that if they can be kept away or killed, decay will not take place.

Fig. 150. — Tumbler containing a slice of potato covered with cotton held in place by a rubber band. Used for growing bacteria.

How to sterilize. One way to kill these tiny plants is to steam or boil them. To test this we may slice a potato and put a slice into each of a number of small bottles or tumblers, as shown in figure 150. Over the top of each tumbler we put cotton wool and fasten it with a rubber band; or we stuff the cotton into the top of the tumbler or bottle as shown in figure 151.

Prepare a dozen bottles or tumblers in this way. We must now *sterilize* them, that is, *kill the bacteria* in them. Place them in a tin pail on the bottom of which is a small pan turned upside down and pierced with nail holes, as shown in figure 152. Pour in water until it stands an inch or so deep on the bottom. Cover the pail with a pan. Now let the water boil in the pail for at least half an hour, and when cool take out the tumblers. Take care that the cotton is not wetted by drops falling from above or by water boiling up from below. We are now ready to make some experiments.

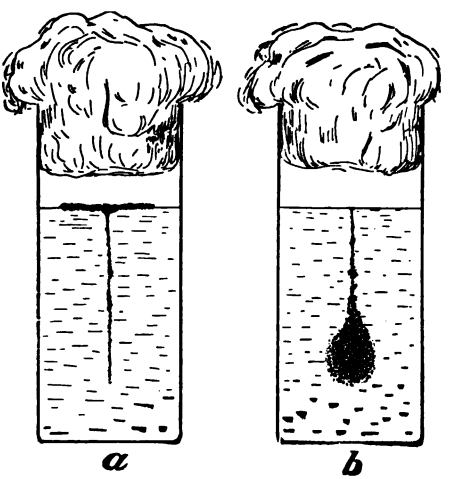

FIG. 151.—Two bottles containing (*a*) bacteria which need air in order to grow, (*b*) bacteria which cannot grow when air is present.

How to grow bacteria. Instead of potato we may use gelatin, which can be made with only a little more trouble and which is very much better for most experiments. Ordinary gelatin such as is used in cooking is placed in about seven times its weight of water. Place it in a pail, as shown in figure 152, with some water in

the bottom of the pail, and allow the water to boil for half an hour. Then to each pint of the mixture of gelatin and water add about twenty drops of strained honey or glucose or a lump of grape sugar as large as a pea (molasses may contain substances which prevent the growth of bacteria).

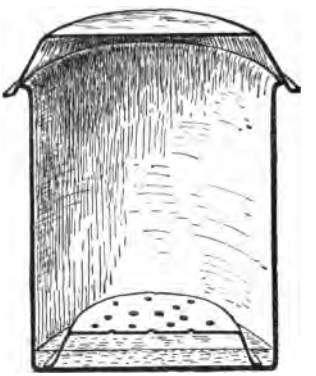

FIG. 152.—A pail for sterilizing. The bottles are placed on the inverted pan in the bottom. (Sectional view.)

Add enough ammonia water, or very weak lye, to make a piece of red litmus paper turn blue when a drop is placed on it. Be very careful not to put in more of the lye or ammonia water than is needed barely to turn the litmus paper blue. Now pour a little of it into each of the dozen tumblers and cover with cotton, as shown in figure 150. It is very much better to use small druggist's vials as shown in figure 151. Also pour a little gelatin into each of two flat bottles such as shown in figure 153, and leave them lying as shown in the figure, so that the gelatin

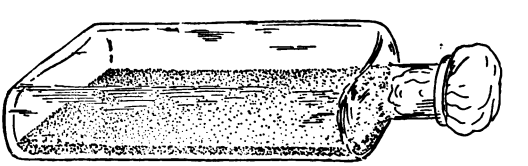

FIG. 153.—Flat bottle containing gelatin, used for counting bacteria.

will harden in a thin layer. The part of the bottle which touches the cotton must be clean and free from gelatin.

After placing the cotton in the bottles we put them back into the pail and sterilize for half an hour more. Let them stand for two or three days. If any spots appear on the gelatin or potato, we must sterilize again. Each spot contains thousands and thousands of bacteria. So long as spots appear, we must repeat the sterilizing. If after standing for a few days, no more spots appear, we know that the bacteria are all dead. If the bottles or tumblers are well sterilized before the gelatin is put into them, it is seldom necessary to sterilize more than once after adding the gelatin.

One of our bottles or tumblers we will leave just as it is. We shall not expect to see any decay in this, because we suppose that all the bacteria are killed. The other bottles we will open so as to put bacteria into them. A good way is to dip a long needle (fastened in a soft wooden handle) or a hat pin into a little water which contains decaying plants, and then stab it right down to the bottom of the jelly, or make a cross with the needle on the surface of a sterilized slice of potato.

How do light and warmth affect bacteria? Put bacteria into four of the bottles of gelatin in the way just described. Keep one of these in the light. Light kills many bacteria, and that is one reason why sun-

shine is so necessary in our homes. We shall not expect so much growth in this tumbler. Keep another in the dark, but be sure to have it as warm as the one in the light. A good way is to cover it with black cloth or with a small box, and set it in the light to keep it warm. Note whether there is more growth in this.

Put another on a cake of ice in a box, and cover it with sawdust or keep it in a refrigerator. Refrigerators are used to keep food from decaying, because the bacteria cannot grow rapidly when they are kept cold. But the cold does not kill them, and so we should not put ice into our drinking water, because the ice may contain living bacteria of the sorts which cause disease. We should put the ice around the pitcher which holds the water, but not into the water itself.

Disinfection. Poisons are often used to kill bacteria. Such a poison is called a germicide. We call the process disinfection. Formalin is one of the best germicides, and we may put a drop of this into the fourth tumbler (or vial). It may not prevent the growth of the bacteria at the bottom of the gelatin, because it may not be able to reach them. This shows us how necessary it is to disinfect a cut or wound by washing every part of it thoroughly with the germicide. The best way is to use a medicine dropper and force a stream of the germicide into the cut; in this way we can cleanse every part of it without pain. If we then dust powdered

boracic acid on the outside and cover with clean linen or cotton cloth or adhesive plaster, the bacteria cannot get into it, and the cut will get well quickly without festering. If we do not take care to keep the bacteria out, we are very apt to have festering sores, blood poisoning, or even lockjaw.

Powdered boracic acid is a very good germicide to have in the house, because it can be used even in the eyes or mouth without danger. The best way is to fill a large bottle with water and put into it enough powdered boracic acid, so that there will always be some of it undissolved at the bottom. As we use up the solution, we add more water until the acid is all dissolved. We must then add more acid. It can be used for wounds or for gargling in case of sore throat, or mixed with an equal bulk of water for use as an eyewash. The mouth should be washed out with it every day, and if any one with a cold in the head is about, snuff up the dry powder in your nose to avoid catching the cold.

Hydrogen peroxide is much used, but it loses its strength in a short time after the bottle has once been opened. Listerine is too weak a germicide to be very useful.

Formalin and carbolic acid are very good for killing the bacteria (disinfecting) in sinks or water closets. Chloride of lime is used in the same way and helps to do away with bad smells, but is not so strong a germicide as formalin. Muriatic acid is also good for the

purpose. Carbolic acid is dangerous, because people may use it on the skin in too great strength. As it causes no pain at the time, they do not find out until too late that they are badly burned.

Corrosive sublimate is a very powerful poison, too dangerous for household use if there are children about. It may be obtained in small tablets.

Are there bacteria in the air? We will now open one of our tumblers or bottles, and expose it for ten or fifteen minutes to the air. At the end of this time we put the cotton back in place and set it in a warm place for a day or two to see whether any signs of growth (spots) appear. The bacteria which cause tuberculosis (consumption) float about in the air. For this reason people who have consumption should not spit except on a paper or rag, which should be burned as soon as possible. Sweeping, especially in schoolrooms, should be done so as to get rid of as many bacteria as possible. Moist sawdust should be sprinkled on the floor. The room should then be swept and left with doors and windows closed until all the dust and bacteria have settled. Then the floor and furniture should be wiped with a moist cloth, which should then be well washed and disinfected. A feather duster should not be used where a damp cloth can be employed, for it merely scatters bacteria into the air. When the feather duster is used, windows and doors should be opened wide. Carpets hold bacteria and are, therefore, not as good as bare

floors covered with rugs which may be easily taken up and cleaned.

Are there bacteria in water? We will now test our drinking water for bacteria. Put one of the flat bottles (figure 153) into warm water until the gelatin is melted. Then take a piece of wire, bend the end into a small loop, pass it once or twice through a flame to kill any bacteria which may be on it, and dip it into the drinking water so as to take up a large drop. Put this drop in the bottle, shake it a little to mix it with the gelatin, put the cotton back into the neck of the bottle, and place the bottle on its side as shown in figure 153. Every one of the bacteria in the drop will grow and make a spot in the gelatin; by counting these spots we can tell how many bacteria were in the drop. Every city has a law which says that the milk or drinking water should not contain more than a certain number of bacteria. The bacteria are counted in the way just described. Test your milk supply in this way and also the bottled water, especially distilled water which is on sale. It often happens that such water has many bacteria in it, because the bottles are not kept clean. Bottled soda water or ginger ale is safe, because the carbonic acid kills the bacteria; this is a good thing to remember when traveling. Never drink from the water tank on a railway train or other public place if you can help it. Get fruit or bottled soda water or ginger ale, instead. Never use a public drinking cup; carry your own cup

or make a cup by folding a piece of clean paper. Drinking cups of paper or rubber may be bought at drug stores.

Each one of the bacteria in the gelatin in a short time produces millions more like itself. We can thus see how a few cholera or typhoid bacteria may quickly infect a water or milk supply.

Colon bacillus. If bubbles of gas appear in the gelatin, it means that your water or milk supply contains bacteria which live in the intestinal tract, and sooner or later cholera or typhoid bacilli may be found in such milk or water. If you find such bubbles, you should report it to your doctor or health officer.

One of the most interesting maps ever made is shown in figure 154. It shows how the cases of cholera, in the great epidemic of 1892, stayed on the Hamburg side of the line, although the city of Altona just over the line used the same water supply. You will notice that in some places all the houses on one side of the street have cholera, while those on the other side do not. The reason is that Altona filtered its water supply, but Hamburg did not.

Filtering the water supply. All that is needed to filter the water is to pass it through several feet of sand. A film or scum forms on the surface of the sand, and this catches the bacteria and holds them back. Twice a day the sand is cleaned by sending a strong current of water through it in the opposite direction. This water

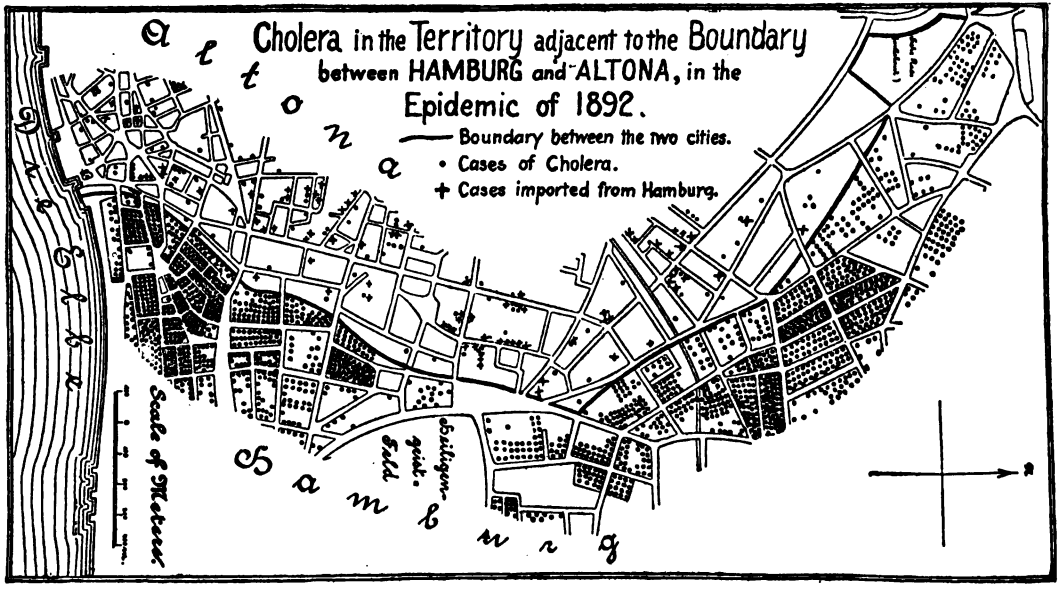

FIG. 154. — Map showing the cholera cases in the great epidemic in Hamburg in 1892. Hamburg and Altona used the same infected water, but Altona filtered it, while Hamburg did not. Hamburg got the cholera, while Altona did not.

is allowed to run into the sewer. The water supply of cities is purified in this way.

The small filters sold for household use are worse than useless, if they cannot be cleaned. If your water is not pure, it should be boiled for a few minutes and kept in a cool place in clean bottles. This is much better than trying to filter it for yourself.

A small filter is now sold by dealers in camping outfits which permits one to suck up water through a tube and filter it at the same time through a piece of charcoal attached to the end of the tube. This should be used when off on walking trips or excursions, except where the water comes from a good spring. Wells are not to be trusted, as a rule, if near houses.

Every town should filter its water. It costs little, and prevents cholera, typhoid fever, and summer complaint.

Bacteria in milk. A pure milk supply is so important that it should be obtained at any cost. First of all the cows and persons who milk them must be clean when the cows are milked. Cloth should be stretched over the top of the pail so that the milk must pass through the cloth first. Then the milk should be drawn out of the pail (without taking away the cloth) by a tube (siphon) reaching to the bottom. It should then be cooled and placed in bottles or cans which have been steamed, and not afterwards rinsed. In cities the milk should be delivered in closed bottles. Milk treated in

this way will keep fresh for several days, because the bacteria, which turn the milk sour, are kept out.

Another way to keep milk fresh is to heat it for a time. Put some fresh milk into each of half a dozen bottles, put cotton in the necks, and sterilize for half an hour. Open one of these bottles each week afterward. How long does it keep sweet?

Steaming or boiling the milk gives it a taste which many people do not like. If we heat it to 155° F. for twenty minutes, we kill most of the bacteria without giving it a bad taste. This is called *pasteurizing*, and helps to keep the milk sweet for some time, especially if it is well cooled as soon as the heating is finished.

Most milkmen will not go to the trouble of providing clean milk or even pasteurizing it, but kill the bacteria by putting in formalin or some other preservative. The effect of this on the stomach is very bad, particularly in the case of infants, and its use is forbidden by law.

Formalin in milk. If the milk contains formalin, we can find this out in a very simple way. Pour a little strong commercial sulphuric acid slowly down the side of a tumbler containing milk. (Great care must be used in handling the acid, as it burns the skin or clothing.) The acid is heavy and forms a layer beneath the milk; if the milk contains formalin, a purple line will form just between the acid and the milk. Before

making this test get a little pure milk and add formalin to it to see how little formalin it takes to produce the purple color.

We notice that the acid curdles the milk; in the same way the acid made by the bacteria curdles the milk. When there is much acid in the milk, it acts as a poison (toxin) to the bacteria and stops their growth. If we add limewater, which combines with the acid and takes away the sour taste, the bacteria can grow again.

Toxins and antitoxins. When disease bacteria, such as those of typhoid, get into our bodies, they produce substances which are poisonous to us (toxins), and our bodies then make " antitoxins " to combine with the toxins and make them harmless. But it often happens that the body cannot do this fast enough, and we must then take antitoxins from another animal which has had the same disease, and put them into our own blood to help in overcoming the poison.

Prevention of bacterial diseases. One way to prevent disease is to do away with all garbage heaps and everything else that is not clean. Stables spread disease because they are breeding places for flies. Catch a fly and put it into one of the flat bottles shown in figure 153. Let it crawl about on the gelatin for a short time and then escape. Put the cotton back into the bottle and let it stand a few days. Do you see any bacterial growth in the footprints of the fly (see figure 155)? When you think where flies came from when

they enter our houses to walk about on our food, you can see why we should do all we can to get rid of them. The fly is now commonly called the "typhoid fly."

If we have pure milk and water, plenty of fresh air and exercise, and keep ourselves and our houses clean, we need not worry about bacteria.

Useful bacteria. There are very many useful bacteria. We could not get along without the bacteria of decay. We need the aid of bacteria in making cheese (page 390), vinegar, hay, silage, and many other things. Each year more and more time and money are spent in studying the useful bacteria, and learning how to make the most of their assistance.

Soil bacteria. Among the most useful bacteria are those of the soil. Some of

FIG. 155. — Bottle containing sterilized gelatin over which a fly was allowed to walk. Each footprint of the fly is marked by a white growth of bacteria. Some bubbles of gas are seen, which show the presence of the colon bacillus.

these are called nitrogen-fixing bacteria, because they take nitrogen (a very valuable plant food) from the air and store it in the soil in such form that plants can use it. Some of these nitrogen-fixing bacteria live free in the soil. Others live in the root tubercles (figure 142) of legumes (such as clover, pea, vetch, lupin, or alfalfa). These plants are plowed under (as greenmanure), and by their decay enrich the soil with nitrogen.

In a compost or manure heap we find some bacteria which cause it to decay and some which make ammonia. Such a heap often smells of ammonia. Other kinds (nitrifying bacteria) change the ammonia into other substances more useful to the plant. They must have air for their growth, and so it would seem best to stir the heap and let in air. But we find other bacteria (the denitrifying) which undo this work and send the nitrogen of the ammonia off into the air. So we should wait until these denitrifying bacteria have ceased their growth. We may then admit air to help the nitrifying bacteria in their work. This we also do in tilling the soil, and the bacteria greatly help in putting the land into good condition.

By knowing how these bacteria act, we may help the work of the useful kinds and check the harmful ones simply by watering and stirring the manure heap and the land at the right time (see page 140).

CHAPTER XIX

THE VARIOUS CROP OR CULTURE PLANTS

To Teachers. — It should be understood by the teacher that the discussions and descriptions of various crops given in the following pages are nowise intended to be memorized, or even consecutively read, by the pupils. They should be used as *explanatory of the objects themselves at the times when these are available,* whether on the farm or in the city markets. The teacher is advised to take up only a few typical forms which can easily be obtained in his locality for illustration, and he should, if possible, enlarge on the objects presented with respect to local conditions or localities of production, thus inciting the home interest of the children, and enabling them to fix the facts in their minds. In the case of crops of great local importance, as *e.g.* in the orange belts, the text of the book should be amplified by short publications bearing on the subject, such as the Bulletins of the Experiment Stations, or the "Farmers' Bulletins" of the Department of Agriculture at Washington. The live teacher can find both in country and city abundant opportunity for imparting active interest in the study of these subjects to pupils from the Kindergarten to the High School age.

The general statements regarding each group of crop plants are printed in large type, and may be used by themselves, but always in connection with the demonstration of actual samples of at least one of the plants within that group.

Wherever a school garden is available, it will be well to

let the children select several of the plants of each group, of the growing of which one or several of them shall take special charge, so as to make them definitely responsible for their care. Such responsibility for particular cultures tends to make the children more careful, and to make them emulate each other in regard to the best results of their work.

The ancestors of the plants we now cultivate in our fields and gardens must have grown wild somewhere before man took them under his care. But many of those that have been long cultivated have been so changed that if their wild ancestors are still to be found, we fail to recognize them as such. Wheat is one of the earliest known cultivated grain grasses, but until recently we knew of no wild plant that we could certainly claim as the original wild wheat. When we speak of wild rye, oats, or barley, we mean grasses that somewhat resemble these grains, but we have not been able to convert them into our well-known grains by cultivation within our time. We can only suppose that the grains originated in the countries where the most ancient history of mankind shows that they were cultivated. Our Indian corn or maize is certainly an American plant, but no wild maize is now found. In the case of maize it is probable that a grass now growing wild but of wholly different appearance has been changed into it by cultivation.

We do know the wild forms of many of our field and garden plants. The beet and asparagus grow wild on

the shores of the Mediterranean. The cabbage group, which includes besides the head cabbage, the cauliflower, the kohlrabi, the Swede turnip, and the collard and rapeseed (called wild turnip in California), is found in the slender form all the way from Europe to Siberia. And when the seeds of any of these are made to grow in uncultivated ground, they soon become like the wild form. The tomato and the potato are growing wild in Chile, and have spread over the world from there. Wild forms of our cherries, plums, apricots, and peaches are still found growing wild in Persia and Armenia. And so with many others.

To show how much the wild forms of plants may be changed by long cultivation, during which more or less selection of kinds specially suited to particular purposes has doubtless been practiced, we may take the various forms of cabbage now being cultivated. Figures 156 and 157 show the most important of these forms.

In figure 156 we see the wild original cabbage plant, now growing in rock crevices on the south coast of England. Toward the right we see how a low-growing plant has been gradually developed into a tree-like form called the Georgia collard, figured from a photograph of a California-grown plant. The Jersey kale, next to it, is doubtless the form from which the collard has been made by selection in America. Next in height is the Brussels sprout plant (figure 157), with small cabbage

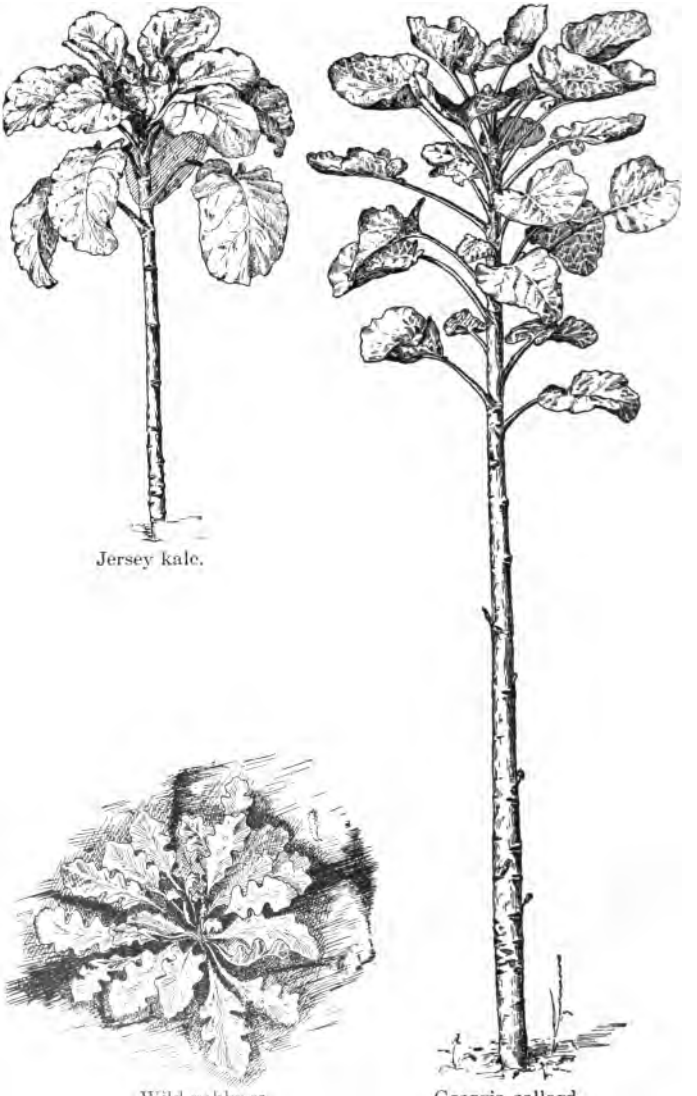

FIG. 156. — Various forms of the cabbage plant, all drawn on the same scale.

Swede turnip.

Brussels sprouts.

Kohlrabi.

Cabbage.

Cauliflower.

FIG. 157. — Various forms of the cabbage plant, all drawn on the same scale as in figure 156.

heads scattered all up and down the stem. Below it we have the common solid-headed cabbage, in which all the leaves of the collard or kale are gathered together into a close-packed mass. Then comes the cauliflower, in which the inner leaves, the flower stems, and flowers are made up into a cheesy mass, a much-esteemed vegetable of much milder flavor than the other varieties. Next above is the kohlrabi, which may be considered as a cabbage head compacted into a turnip-like form, flavored much like cauliflower. Finally there is the "Swede" turnip, having cabbage leaves like the kohlrabi but with the turnip partly underground. So we see how one and the same original plant or forms very similar to it have been varied by cultivation and selection from a tree eight or more feet high to a round turnip. Other culture plants have been similarly varied.

Varieties. Nearly all cultivated plants have many *varieties*, some produced by accident, and many by intentional selection, for the purpose of obtaining or increasing desirable changes for particular purposes. When we sow many seeds of the same kind, no two seedlings are ever *exactly* alike. We can select from them one or several showing some desirable quality, and from the seeds of these make further selections, and so on. Such selections are constantly made by gardeners, who then give new names, such as we see in nurserymen's catalogues, to the variety having some special advantage.

Another way to produce new varieties is by hybridization or crossing, that is, fertilizing one kind of plant with the pollen of another. From the seed so produced we often get some seedlings showing a new or advantageous combination of the two kinds crossed (see Chapter IX).

Varieties must be adapted to climates and soils. However good a crop or fruit variety may be, it may not do well in some particular climates and soils. The best varieties in the Atlantic or humid states may not succeed so well in arid California. The wheat of Minnesota, the best in the United States, loses some of its good qualities after growing for some years in California, or eastern Oregon and Washington. Some of the best Eastern fruits, first tried in California, have now been replaced by varieties originated in California. Our Riverside navel orange loses much of its quality in Florida. The pecan and hickory nuts of the Mississippi states do not produce well in California.

We must therefore *test* crop varieties brought from elsewhere before we plant them on a large scale. We must inquire in what climates and soils they have done well, and then compare these with our own.

Crops for various purposes. Some field crops are grown entirely (or chiefly) for their *seeds*, like wheat, peas, and beans, but the stems and leaves of most can be used also for cattle feed or other purposes. Sometimes all these plants are grown only for their

stems and leaves, and are then called *forage crops*, and fed green, or dried (as hay). Other field crops are grown for their *fruits*, like apples, plums, and oranges, and such small-fruits as raspberries and strawberries. Others again are grown for their thickened *roots or underground stems*, such as turnips, beets, and potatoes. These we call *root crops*. *Vegetables* are food crops for human use, commonly grown in gardens.

Garden vegetables are grown by most families for their own use; but the vegetables supplied to cities are mostly grown in fields called truck gardens. In both family gardens and truck gardens the cultivation is much more thorough, and the soil is kept much more fertile than is usually done in farm fields, because the best quality of the crop is required, and truck farmers must make the most of their high-priced land. Garden crops are always grown in rows, so that they can be cultivated at all times. Like the field crops, they may be grown for their roots, stems and leaves, fruits, or seeds. Some are grown with great profit for their flowers, and flower culture is a separate branch of horticulture.

CHAPTER XX

FIELD CROPS

SEED CROPS

THE most important seed crops are the cereal grains like wheat, rye, barley, and rice, whose seeds are used for human food as well as for stock feed.

Wheat is the most highly valued of the grain crops, because it alone makes good "light bread." That is because wheat contains a stringy, tough substance called *gluten*, which sticks to the teeth when you chew soft wheat. Gluten is best shown when made from wheat flour, as in the experiment explained below. Of the other grains only rye makes a somewhat spongy bread, but of a dark color.

Make up a large tablespoonful of wheat flour into a soft dough, then put it in a linen or muslin bag or folded handkerchief and knead it with your fingers in a pan of water. The water will soon become milky from starch that passes through the cloth. You must keep on kneading until fresh water placed in the bowl does not become milky. There then remains inside the bag a gray, tough mass, which sticks to the fingers

FIG. 158. — Combined harvester.

or the teeth. Put this gluten into a hot bake oven or stove, and it will rise up into a bubbly or spongy mass, showing how bread dough made from wheat flour will rise and make light bread, because the tough gluten keeps the steam bubbles from bursting.

Make the same experiment with oat or barley flour. You will get starch, but no stringy, tough gluten, only a crumbly mass. Hence dough and bread made from the flour of these grains will not rise and become spongy.

Wheat having much gluten is hard and of dark color, and is valued most. When grown in hot, dry climates, like that of California, the hard wheats are apt to lose part of their gluten and become light-colored and soft. So we must from time to time get seed from other parts of the country, as from Minnesota, where wheat has the most gluten.

With a sharp knife cut across a grain of hard and one of soft wheat, and note the difference. Sometimes grains are partly hard and partly soft, and look spotted.

The best wheat is generally thought to be "winter wheat," that is, that which has been sown in autumn and has had time to make deep roots in winter, even under the snow, and to "stool," so as to produce many stems from one seed. Spring wheats are those sown after January in California, or elsewhere, as soon as the frost is out of the ground. Spring wheats are usually softer than winter wheats grown in the same regions. But where no rain falls before winter, as in a large part of the arid region (eastern Washington, Montana, Wyoming), all grains must be sown in spring. For if sown

FIG. 159. — Threshing grain.

in autumn, they would lie in the ground over winter, and would be destroyed by birds, field mice, molds, and bacteria, before they had a chance to come up.

Rye does not need as good soils as wheat, and will stand much more cold; it is often sown for winter pasture. Rye bread is of dark color, and is much liked by many persons on account of its flavor. In Germany and Russia rye is much grown for bread. The "pumpernickel" of Westphalia is made of rye flour.

Barley is the hardiest grain of all, and will ripen in the far north, in Norway, Alaska, and Siberia. Its chief uses are for feeding animals and for brewing beer. Like wheat, barley has many varieties. The Chevalier barley is the most highly esteemed for brewing, and grows finely in the coast valleys of California.

Wheat and barley are much used for hay on the Pacific coast, when sown late so that the grain cannot ripen.

Rice is the grain chiefly eaten in China, Japan, and India. It looks not unlike barley when growing, but requires much water, and is mostly grown in low or swampy ground, and flooded several times. It requires a warm, moist climate, and is abundantly grown in South Carolina, Louisiana, and Texas. It might be grown in California tule lands. Like barley, it has a husk adhering to the grain, which is taken off by pounding or grinding in a hulling mill. It is not made into bread, but eaten boiled in water.

The oat does not look like the other grains, having a branched ear. It is hardier than wheat, and its grains are covered with a hard husk, which is sometimes black or red.

Oats are chiefly used for feed, both as hay and grain. Oatmeal for breakfast mush or gruel is made by sifting after grinding the whole grain, or sometimes from "hulless" oats.

The *wild oat* grows abundantly in California, on natural pastures and waysides, and in fields is considered a weed the world over. Its grain is small and covered with a bristly hull which sometimes chokes stock. But when this oat is cut early, these bristles remain soft and it makes excellent hay; it is sometimes sown on purpose for hay, because its thin stems dry easily.

All these grains may be sown broadcast or in drills, and (excepting rice) their culture is very much alike, but must be varied to suit soils and climate. Wheat is generally thought to require the "strongest" lands, which in the humid regions means clayey soils. But in the arid region, sandy soils being fully as rich in plant food as clay soils, wheat is very largely grown on sandy lands, having very little clay.

Maize, or Indian corn. Maize is an American grain, and was being grown by the Indians when the white men came. It will grow from the Gulf coast to Canada, having many varieties suited to different climates. The flinty ones (hard like popcorn) are more generally grown in northern regions, the softer ones farther south. The great "corn belt," where most of the maize is produced, runs east and west from Illinois and Iowa. Maize is not much grown in California, because other crops pay better, except for green summer feed and silage. Maize will stand much dry weather

when it has a chance to root deeply, and for green feed is often sown broadcast.

Maize is the largest of all grain crops in the United States. Its largest uses are as food for hogs in pork production, for the manufacture of starch, and of sweet sirups (glucose), candies, alcohol, and whisky. Much of it is also eaten as corn bread, but maize grain cannot be ground as fine as the other grains, because it contains too much oil; and for that reason corn meal becomes rancid if kept long, just as butter and lard do. The oil is valuable because from it is made a substitute for rubber. Maize is also much eaten as "roasting ears," preferably from the varieties known as sweet corn, which grow very rapidly. Maize is also grown in southern Europe, where it is miscalled "Turkish wheat"; also in South Africa, where it is called "mealies"; and likewise to some extent in Asia. But the natives of both continents have long grown sorghum instead, as their most important grain.

Sorghum has several varieties which we cultivate under various names, such as Egyptian corn, broom corn, durra, Kaffir corn, milo maize, etc. All sorghums look much like maize in growth, but instead of bearing ears and tassel, they bear perfect fruiting flowers at the end of the stalk, and there produce smooth, rounded grains of various colors, which can be used just like maize grain.

When broom corn is grown, the seed-bearing tassel is bent sharply so as to hang downwards while still green; it is from such tassels that our common sweeping brooms are made. The various sorghums are largely used for feeding

cattle, both green and for silage, and to some extent for making molasses from their sweet juice, like the Minnesota amber sorghum. This is best grown in humid climates, and does finely in eastern Oregon and Washington, while the Egyptian, milo maize, and durra can be grown in arid soils with very little moisture; as may be seen in the San Joaquin Valley of California.

The sugar cane proper belongs to the tropics and is now hardly seen in California, as it does not pay.

LEGUME SEED CROPS

Beans and peas. In California lima beans and white navy beans are grown extensively, especially on the southern coast of California, but also in the Great Valley. They are mostly sold in the Eastern states. Beans, peas, lentils, and vetches are very nourishing; when necessary, men can live on them alone for quite a while, as mining prospectors have sometimes had to do. In Mexico and southward, too, the dark-colored beans (frijoles) grown there are almost daily fare. The broad or horse beans, as commonly seen in the gardens of Portuguese and Italians, also make a dark-colored though very nutritious dish.

The **cowpea,** really a bean, with very long and narrow pods crowded with seeds, is a great favorite in the Cotton states and in India (Catyang), where it grows very freely; in California it often suffers from the hot, dry winds.

The **soy bean,** from which in China and Japan the "soy" (properly shoyu) sauce and vegetable cheese are made, does

not do well in California; it is affected by the hot, dry winds. When sown, the root bacteria peculiar to it have to be put into the land.

A large number of *lupins* grow wild in California and in the Great Basin states, but the bitter taste of both herbage and seeds prevents their being eaten readily by either man or beast. Their best use is for greenmanuring.

The **peanut,** or gouber pea, is grown in sandy soils in the Great Valley of California, as it is all over the warm portions of the earth. It is curious for bearing pretty yellow flowers that bear no seed, while buds from the lower side of the stems, which have never opened to bloom, force themselves into the ground (which therefore must be soft or sandy) and there grow into the well-known "nuts." These contain much oil, which is pressed out and used for burning and eating. As the flower shows, the peanut is a true bean or pea.

FORAGE CROPS

The grasses have always been the chief among the forage crops, because they form most of the natural pastures all over the world, and yield the bulk of the hay. Next in importance to them are the legumes, in this connection particularly the clovers, which include alfalfa. A very important thing in growing legumes is the fact that they enrich the soil in nitrogen (see page 141), while grasses take nitrogen out of the soil. For this reason legumes should always be used for greenmanuring, or plowing in of green crops (page 128) to enrich the land, to which grasses and grains only

give back what they took from it. Legumes should therefore never be called grasses, as is sometimes done,

FIG. 160.—Hay making in the old-fashioned way (compare with figure 161).

for they have a wholly different place in agriculture, as well as in botany. A number of other leafy plants are also among forage crops.

GRASSES

Nearly all the real grasses serve for pasture when young, and most of them can also be cut for hay when older. The best time for haying is when the grasses are just beginning to bloom.

The flowers of grasses are not pretty or conspicuous. They have no colors to attract insects, but we can easily tell when they bloom by the long stamens with yellow anthers (see page 92) hanging out on the flowering ear. This ear is sometimes simple, as in wheat and other cereal grains, timothy, and foxtail; but more commonly branching, as in oats and most pasture grasses, from which very pretty bouquets can be made. There are so many kinds of grasses that only a few of the most important can be mentioned here, and many are not easily told apart. But "everybody knows a grass when he sees it," unless, as in the case of maize and sorghum, some may think it too big. Nearly all grasses have leaves with long blades, and veins running only lengthwise, not netted, as in most other plants. And there are no poisonous grasses.

The native grasses of the Pacific Slope mostly grow in tufts or bunches, not as a continuous sward like the blue grass, or June grass, of our lawns, which comes from Europe. This is because runners and root stocks cannot readily spread in the dry surface soil. There are, therefore, many kinds of "bunch grasses" in the arid regions, most of them highly esteemed for pasture, while others are hard and wiry and not liked by cattle. But the native pastures should be carefully kept from too much grazing or "overstocking." Few native grasses are as yet cultivated, though some of them deserve it as much as many brought from elsewhere, since they are known to suit the climate.

Of cultivated grasses, the most widely used is probably

the **ray grass** (commonly miscalled rye grass; it does not resemble rye at all), which is also used for lawns, because it needs less water than blue grass. It is also sown for pasture, and makes good hay. The **cocksfoot** or **orchard grass** also does well, and however dried-up it may look in summer, it always puts out green leaves as soon as moisture comes. It grows in tussocks or bunches, and will not do for lawns.

Bermuda grass, known all over the world, is somewhat used for lawns and pastures. It seldom bears seed, but we propagate it by cutting the stems into small pieces and then scattering and covering them like seed. Its root stocks are hard to get out of the land when once set. It looks somewhat like alkali or salt grass, but the bloom is very different and the leaves wider.

Hungarian brome grass is one of the best grasses for hay and pasture on dry lands. Of the many brome grasses common in California, only the soft brome grass, much seen on natural pastures, is of much value as cattle food. Most brome grasses are weeds.

In northwestern California and in western Oregon and Washington the hay grasses used in the Eastern states, such as **timothy, foxtail,** and **redtop,** grow very well, and are much used for hay, in addition to cocksfoot and ray grass. Timothy and redtop need abundant irrigation when grown in a dry climate, and do not pay as well there as ray grass and cocksfoot grass.

Weed grasses are mentioned in Chapter 14.

LEGUME FORAGE CROPS

Legume forage crops. Among the legume forage crops, *alfalfa* undoubtedly holds the first place in the

arid region. Here the great depth and easy penetration of soil and the number of successive crops which can be obtained with irrigation, render it far superior to the clovers, which are preferred throughout the humid region to the "lucerne," the name there given to alfalfa.

Alfalfa is one of the most anciently known forage crops. It was supposed to have originally come from Media (northern Persia), and is called the "Median herb" by ancient Latin writers. In southern Europe it is to-day the chief forage crop. It requires a warm climate and a deep soil, for its roots are said to go down fifty feet at times. In the Great Valley of California it very commonly goes to twenty-five feet depth. That is why it will stand so much drought, for at such depths the land is always moist. It may then continue to grow on the same land for thirty years without sowing again.

Alfalfa may be fed green, but most of it is made into hay, which is very good food. When irrigated (figure 25) immediately after cutting, it quickly grows up again, and as many as six cuts have been made from fields in southern California. So with irrigation it is a very profitable forage crop, yielding as much as ten tons of hay to the acre, when grasses would have made only two to four.

Red clover in its several varieties is to cool and moist climates, such as the East, and western Oregon and Washington, what alfalfa is to warm and arid ones. It does not root as deeply as alfalfa, and hence will not stand the summer drought of California without

FIG. 161. — Stacking alfalfa hay in Idaho. (Notice how much better this way of stacking is than that shown in figure 160.)

very frequent irrigation. In northwestern California, and in western Oregon and Washington, it grows very well and is very profitable.

In the eastern United States and in Europe it is an invaluable crop in "rotations" with grain and root crops, and is usually plowed under after the second year as a green-manure crop, enriching the soils with nitrogen and humus. Like alfalfa, it is fed both green and as hay; when fed green to stock, it is apt to bloat them when much is eaten at once.

In California red clover has been grown in the foothills of the Sierra, with irrigation. In the valleys it is not often grown, as it is apt to "burn" when hot, dry winds blow.

Crimson clover, a beautiful kind with long red flower spikes, is very highly valued in the East, but is not adapted to California. It grows finely in western Oregon and Washington, and yields heavy crops.

The same is true of the **white clover,** which we grow on our lawns with constant watering. In the East and in the Northwest coast country it grows splendidly and forms valuable pasture, but is not suitable for hay.

There are no fewer than twenty-two kinds of clover native to California and other dry regions of the Pacific slope, but with few exceptions they are annuals, and as their foliage is usually a little bitter, they are not much liked by stock. There is one kind, called the **wormskiold clover**, however, which looks very much like the common red clover and is perennial. It grows in damp or even wet ground, and may sometime become valuable in cultivation.

The **bur clover** is well known all over California. It is

not liked by stock when green because of some bitterness. It bears burry seed pods with hooked bristles, which remain on the ground during the dry season. As these are full of food, they form a very valuable part of the "dry pasture" which helps to carry stock over summer. But when sheep are allowed to run on such pastures, the burs get into their wool and greatly lessen the value of the wool in the market. The bur clover also serves as a good greenmanure, and so, although a weed, is not unwelcome.

The vetches may be known by their "compound" leaves with many small leaflets on one stalk, like the wild one that grows all over the Pacific Coast. There is one, the hairy vetch, which is much used as a greenmanure plant and also for hay. It has very beautiful dark pink or red flowers, and forms a heavy mat on the ground with its twining stems and leaves.

The hairy vetch, and the Canadian field pea (which differs little from the common garden pea), the Ochrus pea, and several others imported from Algeria are used as greenmanure crops (page 141), because they grow during the mild California winters and can be plowed under in early spring, so as not to waste the moisture needed by orchard trees or vines.

The **lentil** is a small vetch, with lens-shaped seeds, which have long been esteemed as a good food to replace meat in times when meat is not to be eaten. Hence the name *Lent* for the forty days before Easter.

ROOT CROPS

The various root crops are plants having enlarged or swollen roots or underground stems, such as turnips

and potatoes. Sometimes they have swollen leaves, as in the case of onions. The size of these swollen parts has been greatly increased, by cultivation and selection, from that which is found in the wild plants. Thus the "wild turnip," which is a common weed in our fields, shows little indication of the possible development into the Swedish turnip or ruta-baga, or into the cabbage. And the wiry root of the wild radish of our fields does not much resemble the tender breakfast radish from which it is derived. Similarly, the large mealy potatoes in our markets do not greatly resemble the little tubers as large as a marble which we see in the wild potato of Chile.

As tubers must grow larger in the soil, it follows that the soil must be kept loose around them, unless it is naturally sandy. Hence they are "hoed" crops, and need cultivation during their growth. We have in the case of beets and turnips varieties which grow mainly above ground, and are therefore less particular in regard to soil and cultivation.

Root crops take a great deal of potash from the soil, and soils and fertilizers must be adapted to this need. They are used very largely for human food as well as for stock, but along with them other foods must be eaten which contain more nitrogen and phosphates. Such foods are grains and legumes, or (for stock) hay.

The potato, commonly called Irish potato because

it is the most common food in Ireland, grows wild in Chile. It was found in cultivation (in northern South America) when America was discovered. It was introduced into Europe toward the end of the sixteenth century, both by the Spaniards and the English. The English brought it from Virginia to England, where at first people attempted to use the ill-flavored and poisonous leaves as a pot herb. It is said that this mistake caused Sir Walter Raleigh, who had sent the plant, to be suspected of intending to poison Queen Elizabeth. He was exonerated when it was explained that only the tubers were to be eaten. After this the potato spread rapidly over Europe, and largely took the place of other root crops, such as beets, turnips, and carrots. These are now mostly fed to stock.

Potatoes contain more starch than any of the other roots mentioned, and can be cooked in a greater variety of ways. As they do not have a strong flavor, one does not get tired so easily of eating them, just as is the case with bread. In Europe the potato is largely used to make starch and alcohol.

Potatoes are not grown from seed, but whole or cut tubers are planted in rows about three feet apart. The tubers are underground stems, and are quite different from the real roots. Their "eyes" are buds, and from each eye we can grow a plant. But unless we leave a piece of the potato tuber to nourish the growing bud at first, the plant will be weak and will not bear well. In some seasons the potato vines will bear many green berries. These, like the leaves and stems of most of the nightshade family, to which the potato belongs, are ill-tasting and poisonous. So also are the potato

sprouts that grow in spring, and any part of the potato itself that has turned green by exposure to light.

The chief troubles to which the potato crop is liable in California and on the Pacific Slope generally are the potato worm and the scab (see page 247). The striped potato beetle, which has given so much trouble in the East, has not reached the Pacific Coast.

The sweet potato, or batata (whence the name "potato"), has been known and cultivated much longer than the "Irish" potato, both in South America and Asia. It belongs to the morning-glory family. It makes long vines that climb and twine when given a chance, and has yellowish white morning-glory flowers when the season is long enough. It grows best in warm, temperate, and tropical climates, and is cultivated in such countries all the world over. Unlike the common potato, it is an enlarged root, which has no buds or "eyes." But if buried in a hotbed with plenty of manure, it will make many sprouts or *sets*, which can then be set out in the fields.

In warm, moist climates the sweet potatoes are often cut into pieces like the common potato for planting. This plan is not so successful in the dry climates of the Pacific Slope. Here it is grown in rows on level ground, while in the Gulf states it is always planted on ridges thrown up by the plow, so as to prevent its getting drowned out in case of heavy rains. The roots grown there are much sweeter and less starchy than those grown in dry climates or farther north.

There are a great many varieties of sweet potatoes; the

most common are spindle-shaped and less than a foot in length, but some are almost round. A kind often fed to cattle sometimes measures two feet or more in length, and five inches in thickness.

Sweet potatoes are eaten boiled, steamed, baked, or fried in slices, but do not lend themselves to such a variety of dishes as does the common potato.

Beets. Of the beets we know with certainty that their wild ancestor is at home on the shores of the Mediterranean Sea, where it grows a slender taproot. It was probably first used, as it still is to some extent, as a pot herb like spinach. As the root is easily enlarged by cultivation, it has now been developed into numerous varieties used for different purposes. A very large variety, having the bulb chiefly above ground, is called mangel (properly mangold-wurzel), and is extensively grown for cattle. A smaller kind, or group of kinds, has by seed selection been so increased in sugar content, that it is now the chief source of the world's sugar supply. It is approached only by the tropical sugar cane, which at one time was almost the only plant from which sugar was made.

The sugar beet is now extensively grown in California, where more beet sugar is made than in all the rest of the United States. To make sugar profitably from beets requires very large and costly manufacturing establishments. It cannot be made on a small scale, or at home. Beet sugar rightly made can be used for preserves and jellies just like cane sugar. Beet molasses, known as blackstrap, is not as pleasant to the

taste as cane molasses, and is mostly fermented into alcohol. The refuse beet pulp is an important cattle food.

Beets, especially the red variety, are also used as a kitchen vegetable, for cooking, salad, and pickles.

Beets of all kinds are sown in rows or drills, about two feet

FIG. 162. — Growing sugar-beet seed in Utah.

apart each way if large tubers are to be grown, or only ten inches in the row if small roots are wanted, as in sugar beets.

Turnips are of two chief kinds, readily distinguished by the leaves. In those of the "Swede" type the leaves are similar in color and surface to the cabbage, while the other group, the common turnips, have the rough and dark leaves of the mustards. The flesh of the common turnips is white,

or nearly so, often with a tinge of red. The Swede turnip, sometimes also called ruta-baga, has yellow flesh, which is also generally sweeter than that of the common turnips.

On account of their rapid growth turnips of both kinds are commonly sown as *second* crops after the grain harvest, especially in the humid regions, where summer and autumn rains can be looked for. They can there be harvested before frosts set in, and are stored away in cellars or pits, or in piles, well covered with earth, to keep out frost.

Turnips are very important as winter food for stock in all north temperate countries, to be fed along with the dry feeds, like hay.

The **"Jerusalem" artichoke** has nothing whatever to do with Jerusalem, being a native of Canada and the northern United States, where it was cultivated by the Indians before the whites came. "Jerusalem" is here a perversion of the Italian name for a sunflower (girasole). The plant is a sunflower, little different from many kinds now growing wild in the Mississippi Valley states.

Its tubers, like those of the "Irish" potato, are really underground stems, and can be made to grow up into flowering stalks if put above ground. They are smaller than the average potato, also softer and more watery, but have a flavor not unlike the true artichoke. They are little used in cooking except in soups. As a cattle food, they are very good, and in good soils yield heavy crops. The tubers are used to propagate the plant.

Hops. The hop plant grows wild in Europe, and has been cultivated for the brewing of beer only since

the Middle Ages. It has also run wild in some parts of the United States. As a crop it is grown all over the north temperate part of the civilized world. It will climb high on trees and is often used as an ornamental climbing vine.

Its flowers are green and not beautiful. The fruit, which is a cone of small green leaves on which the seeds are borne, is chiefly used in brewing beer, to impart to it a pleasant flavor and a slight bitterness. It is also used for soothing poultices, and in pillows for those who do not sleep well. Its chief properties are contained in the yellow powder which covers the inside of the cone leaves.

Hops are usually sown first in the nursery and then set out in rows; later they are supported on trellises or hop poles. The cones are gathered by hand before they are ripe, then dried and packed in bales. California grows excellent hops, but the cost of hand labor makes the crop unprofitable in some years. In western Oregon and Washington, also, hop growing is an extensive industry, and the quality is excellent.

FIBER CROPS

There are in California and in the Pacific Northwest many wild plants whose stems have a fibrous bark. When cleaned the fiber is very handsome and strong. Such plants are the common milkweeds, the turkey weed, Colorado River hemp, and many others; and people often wonder why they are not used for spinning and weaving. If you take the dry stem of any milk-

FIG. 163. — Hop field.

weed and break it, then work it with your fingers, you can get out the fine silky fiber and try how strong it is.

Then again, very many of the plants which elsewhere are grown for the production of commercial fibers, grow excellently in California. Such are flax, hemp, cotton, ramie, and many others, which not only yield first-class fiber, but also very heavy crops. Flax and hemp also grow finely in Oregon and Washington. Why then are these crops so seldom grown by farmers, and when grown soon abandoned?

The cause is simply the excessive cost of hand labor, which in these crops cannot be replaced by machinery to sufficient extent.

The only fiber plant grown on a large scale in the state of California at this time is **flax,** and this not so often for its fiber as for its seed, from which linseed oil is pressed. Poultices are made from flaxseed in cases of sickness, because the seeds are coated with a layer of gum which swells up in water; so that the seeds will take up four or five times the room they took when dry. Try this in a vial nearly full.

The cultivated flax, which is a native of the Old World, has very pretty blue flowers. Another flax with red flowers is often seen in gardens. In the Great Valley of California, and also in Oregon and Washington, we find on the drier lands a wild flax with small yellow flowers, which also has a very strong, fine fiber. So you see that California and the Pacific Coast, generally having native flax, would be just the place to grow it to the best advantage, if hand labor were not so expensive. Linen, made from flax fiber, is on this account more expensive everywhere than cotton goods.

Cotton, which, unlike flax, is the fiber that surrounds the seed, also grows well in the valleys of California when irrigated, and has a particularly fine, long, and strong fiber. But it was found that it cost so much to pick it by hand, as is done in the Cotton states, that it would not pay to grow it. It was tried in the Great Valley over twenty-five years ago.

Excellent **hemp,** from Japanese seed, has been grown in Butte County, California, for a number of years. But although largely worked by machinery, it has not paid very well. In Oregon and Washington also hemp does well.

Our native **nettles** have a very fine silky fiber, resembling that of ramie; and in olden times nettle cloth was made in Europe for very fine articles of dress.

Ramie is the finest and silkiest of all plant fibers, and is also very long and strong. The ramie plant, which comes to us from southern China, looks like a nettle, but has no stinging hairs. It grows well in the valleys of California, and will in the southern part make three and even four crops a year. But here again, hand labor in harvesting and in tending the machinery required to get out the clean fiber renders it unprofitable. The fiber used comes mostly from China, where labor is cheap, and is sometimes called "China grass." It serves to make the finest cambric handkerchiefs and sewing thread, and owing to its luster is used to form half (the "web") of cheap silk goods.

Silk is raveled from the cocoons spun by the silkworm, originally brought from China; it is therefore an animal fiber, like wool. Silkworms, or rather caterpillars, feed on mulberry leaves, and both the tree and the worm do finely in California, and can be cared for as a home industry by children and women very successfully. But on a large scale it does not pay to raise the worms, because it requires close

attendance from careful persons who have to be paid highly and can only be occupied for a few months in the year. Besides, the worms are liable to suffer from sickness when in large numbers unless great care is taken. So silk raising is almost altogether household work, in China, Japan, Italy, France, and Spain, where most of the silk is grown. If you plant a few mulberry trees, you can, when they are old enough, get silkworm eggs from the Department of Agriculture at Washington, and raise the worms and cocoons, which is a very interesting piece of work.

CHAPTER XXI

ORCHARD FRUITS

EXCEPTING the citrus fruits, nut trees, and the olive, nearly all the fruits grown in our orchards belong to the rose family of plants. These are in two groups, namely, *stone fruits*, which have a single seed or pit,

FIG. 164. — Fruit orchard in the plains country, Utah.

like cherries, plums, peaches, and apricots; and *pome fruits*, which, like the pear and quince, have from five to ten seeds, forming a "core" in the center of the fleshy fruit. If we cut an apple across, we see the five seed-vessels, each with two seeds. Wild apples (crab apples)

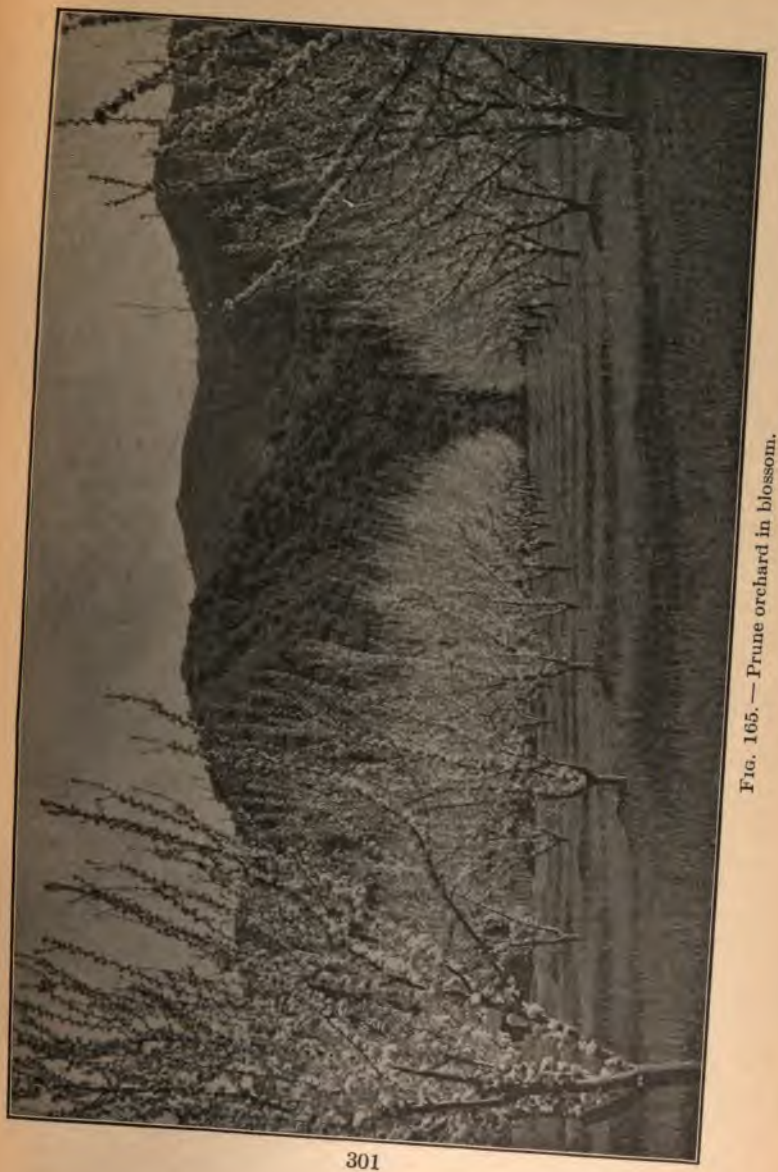

Fig. 165.— Prune orchard in blossom.

are found in middle and southern Europe and adjacent parts of Asia, as well as in North America. Apples like rather a cool climate, and in California grow best in the coast region and in the foothills of the Sierra Nevada, at 3500 to 4500 feet elevation. Farther north, excellent apples are grown in Oregon, especially on the Umpqua and Rogue Rivers. Stone fruits, particularly plums, prunes, and apricots, are largely grown in nearly all the valleys of California, together with pears, which require a somewhat warmer climate than apples, and rather deeper soils. Stone fruits, apricots excepted, are also very successfully grown in Oregon and Washington, and so are pears and apples, notably in southern Idaho. All these fruits are shipped to the Eastern states in large quantities (especially from California), some fresh, and others dried or canned.

Orchard fruits are always grafted so as to have the desired kinds, varying according to climate, soils, market, and soon we must have different stocks to graft on, also, for dry, sandy, and alkali soils, and for moist or heavy soils. Grafting on quince stock is frequently done to make dwarf trees of pears and apples. Apricots do not do well on almond stock, but peach and almond may be grafted upon each other.

Standard height fruit trees are usually planted twenty-five to thirty feet apart; to secure a high quality of fruit the trees should be regularly and properly pruned. The ground should be kept well cultivated, and in California it is usual to keep a surface layer of fine earth five to six inches deep,

Fig. 166. — Packing apples, Oregon.

to prevent loss of moisture during the dry season. This is apt to make the soil lose much humus by sunburn; so we must then grow greenmanure crops, or use plenty of stable manure, to give it back. But any such crop growing during summer in arid countries will take much moisture from the land; it should, if possible, be grown in winter and be plowed under in spring; weeds must not be allowed to grow in summer.

In harvesting all fruits it is very important not to allow them to be chafed or bruised (page 231), as this will cause early decay and make them unsalable. And after gathering, the fruit should be kept in a cool, dry place unless wanted at once for drying or canning. If it is to be shipped a long distance, it should, if possible, be cooled with ice *before* being put in the car, as it will then keep much better.

For drying and canning, apples and pears are sliced after peeling and coring. Peaches and apricots are sometimes canned whole after taking the skin off by dipping in hot lye, or peeling. But mostly they are halved and the pit taken out. Plums and prunes are dried after dipping in lye to thin the skin, or after pricking with needle points, or both, when they dry most rapidly. The fruit is then spread out, whole, in the sun, on trays that keep them off the ground. Figure 167 shows how this is done. In damp weather, or when the Weather Bureau sends warning of rain, these trays are stacked and covered with tarpaulin.

Sun-dried fruit is mostly "sulphured," by burning sulphur under it in closed boxes, first in the freshly cut and then in the dried condition, to prevent fermentation, kill insect eggs, and to produce a light color.

FIG. 167. — Drying prunes.

Where sun-drying is difficult on account of summer rains, as in the Eastern states and in parts of Oregon, Washington, and Idaho, fruit is dried with artificial heat in driers, where the trays are stacked so as to make dry, hot air pass zigzagging over them. Such driers are little used in California now.

CITRUS FRUITS

Oranges, lemons, and grape fruits can be grown only where frosts occur rarely or last but a very short time; as in southern California, and on the lower slopes of the mountains and valley borders, where cold air flows away soon. They are sometimes protected from frost injury by clouds of smoke smudging. Their original home was probably southeastern Asia, from India to Cochin China, and perhaps southern China also. The wild orange is sour, and is used as hardy stock for the sweet kinds and for lemons. Having been so long cultivated, citrus fruits have innumerable varieties, ranging in size from that of a pecan nut to that of a child's head, and grown for various purposes in different countries. In California we grow for marketing about a dozen varieties of oranges and half as many of lemons. Oranges are less affected by frost than lemons, and are grown as far north as Tehama county. They ripen earlier in middle California than in the south.

Citrus trees need much moisture and are mostly grown with irrigation, which should be done in *deep* furrows, so as

to make the roots go as deep as possible (page 53), and make frequent irrigation and fertilizers less needful. Fertilizers should be put in deeply, so as to make the roots go down instead of spreading near the surface.

FIG. 168. — Orange orchard. (Notice the mulch.)

Oranges and lemons are known and used all over the world. The rinds of oranges and lemons are pressed or distilled for flavoring essences, and the flowers of both are gathered and distilled to make much-prized perfumes, of which oils of neroli and cedrat are best known.

Flavoring extracts of lemon and orange can be made by simply letting the outside rind of the fruit soak in alcohol; but most of the commercial extracts of this kind are now made by dissolving the ready-made oil in alcohol. Many

of these commercial extracts are very weak compared to their cost, and home-made extract, or the rind itself, will often be used in preference.

OTHER ORCHARD CROPS

The **olive** is perhaps the most anciently known fruit tree, its branch being mentioned in Genesis as having been brought to Noah's ark by the dove. It is also

FIG. 169. — Picking olives.

mentioned as having been promised to the Hebrews when they should reach the land of Canaan. It is now found wild (oleaster) and cultivated in countries on the Mediterranean Sea. It was brought to California

from Spain by the Franciscan missionaries. The "Mission olive" is still widely grown in California. The olive wants a warm, dry climate. It will not stand much cold, and in moist tropical climates it will not bear fruit. So California and Arizona and parts of New Mexico and Texas are the only states of the Union where the olive will grow and bear well. To do its best it needs some irrigation, although it will grow on hill lands with fairly deep soils.

The flesh of the olive has been pressed for oil from ancient times, and its oil is used for salads and cooking all over southern Europe instead of lard or butter. California is now producing very good olive oil, but most of that used in the Eastern states still comes from France and Spain. Olive oil has none of the tartness which makes a fresh olive uneatable. When the tartness is taken out by soaking in weak lye, and the fruit is then put in salt brine, we get the delicious pickled olives. Some are pickled green, but the best are the pickled ripe olives, which are a very good food, easily digested, and are a very common food in Spain and Italy.

Olive trees are best grown in good uplands. In low, moist ground the fruit is watery and the oil made from it inferior. But it is a mistake to think that olives can be profitably grown in poor, stony lands. Some people who have seen olive orchards in Italy on stony hillsides have not observed that the trees are growing in deep soil thrown up in steps (terraces) by hand, which are kept heavily manured and make fine crops.

Before Congress enacted the pure-food laws, olive oil was very commonly mixed with cotton-seed and other edible oils, and sold as pure oil.

Grapes. The grape is mentioned in the Bible next after the olive, as having been given to Noah shortly after he left the ark. The European vine is found wild and climbing over tall trees in the forests on the eastern shores of the Black Sea. In cultivation it has been

FIG. 170. — Vineyard.

developed into more than a thousand varieties, white, red, blue, and black; some with solid flesh, used chiefly for eating and raisin making; some with juicy, soft flesh, used in making wine. Of both kinds some bear best when allowed to climb like the wild vine, while others need to be pruned short in order to get the best fruit.

Most of the eating and raisin grapes are pruned quite short, that is, within two to four buds of the last year's growth (canes), and such vines are grown only with one stake, and

FIG. 171. — Giant grapevine at Carpenteria, California.

sometimes none. The long-pruned vines are sometimes allowed to run over trees in Italy, but in California are mostly tied to trellises of wire or wood.

All grapes grown in the Old World are of the European kind, and they were taken to America in early times. But

it was found that after a few years they would begin to suffer and finally die, mostly, it was thought, on account of severe winters. As there are many kinds of native vines growing in the United States, people tried to improve these by cultivation, like other fruits, and succeeded very well so far as eating grapes go. But the American grapes all have a peculiar spicy or "foxy" taste, somewhat like the European "muscat," and made wines quite unlike those of Europe. Then it was discovered that the reason why European vines die in America is that the roots are attacked by a very small mite or louse, called the phylloxera (page 213), which is originally at home on American vines but does not hurt them much. So it was found that where the cold is not too great in winter, the European vine can be grown when grafted on American stocks. In the meantime the phylloxera had found its way to Europe itself, and killed hundreds of thousands of acres of vineyards, particularly in France. So the French had to graft all their vines over on American stocks, and for a number of years there was great distress among the vineyardists. But now that the grafted vines have all come into bearing, there are more grapes and wine in France than ever. This country, which had infected the French vines with the parasite, also furnished the remedy for the disease.

In California the phylloxera has spread all over the northern part of the state, but has not as yet reached southern California. Therefore new vineyards northward of the Tehachapi Mountains should all be planted with grafted cuttings in order to be safe from the insect.

California alone of the United States produces wines and raisins like those of Europe. Wines are made by crushing the grapes and then fermenting the juice, either alone or with the grapeskins. When fermented on the crushed

black or blue grapes we get red wines. This takes the color and tannin (astringency or tartness) from the skins or pomace. When the juice is fermented alone, we get a white

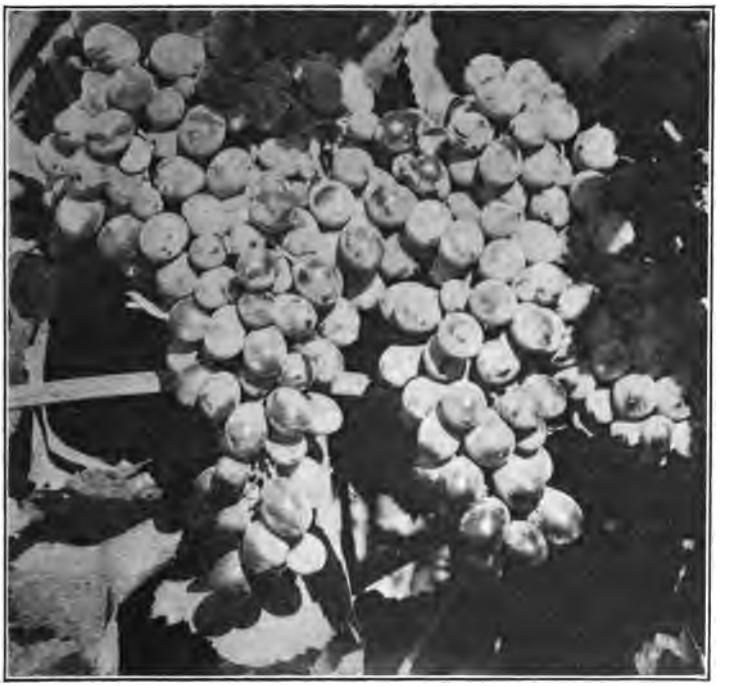

FIG. 172. — Tokay grapes.

wine. After the wines are fermented they must be kept in casks to be "matured" for one or two years before they can be sold.

Raisins are made in California by drying the grapes on large trays in the sun; they cannot be made where the summer is foggy. Most raisins are made in the Fresno

region, also some in the Sacramento Valley, and elsewhere.

Large amounts of grapes are also eaten and shipped fresh. For this we use mainly the fleshy, solid kinds, which do not easily break in handling, such as Tokay, Muscat, and others. Most of the moldy grapes found in market have been injured in handling or packing; this can easily be prevented by proper care, and by cooling before shipping.

NUT TREES

Of trees bearing what is commercially known as nuts, the almond, "English" walnut, and pecan are the chief.

The almond tree is much like the peach, and as there are almonds with fleshy husk, it has been thought by some that almond and peach are merely varieties of one and the same wild tree.

Almonds are very liable to be injured by frost when in bloom, which comes very early, and so they are grown on slopes rather than in valleys; they do not like heavy clay soils. Sweet almonds are grown for eating and for pressing oil, but bitter almonds are poisonous, like peach kernels; they are usually first pressed for their sweet oil, and then distilled with warm water, so as to obtain the "oil of bitter almonds," much used for perfuming soaps.

Walnuts. We have a wild walnut in California, and in the Eastern states the "black walnut," growing in rich bottom lands, is much prized for both fruit and wood. But what is commercially known as the "English" walnut is at home all the way from Europe to

eastern Asia, and is cultivated all over southern Europe and middle Asia. It probably came to America from England.

Walnuts are grown very largely in southern California, but do well in the Sierra foothills and the Coast ranges. They are often grafted on the native or the black walnut stock.

Both almonds and walnuts, after their outside hulls have been taken or have fallen off, are usually of darker tint than is desired. They are therefore bleached, either by burning sulphur, like other fruits, or are dipped into bleaching fluids, which make them lighter colored and more uniform. But this bleaching must be carefully done, for nuts that are slightly cracked will get the bleach inside and have the kernel spoiled.

The oil in nuts becomes rancid after a while, and makes them unfit to eat. They will usually not keep sweet more than a year.

The **pecan** nut is at home on the moist bottom lands of the southern Mississippi Valley states, notably Louisiana and Texas, where rains are abundant throughout the year. It is there a tall, beautiful tree, and bears abundantly. It has not thus far been very successful in California, although some good trees are found here and there.

The **filbert,** or large European hazelnut, much seen in our markets, is not as yet grown to any extent on the Pacific Coast; although the fact that a native hazel grows on the Coast ranges would seem to show that it should succeed well. It deserves further trial.

The **chestnut** tree has not thus far been grown very much on the Pacific Coast. In its native region (Europe and the southeastern states) it dislikes limy soils, such as we have for the most part, and it likes moisture.

As with the pecan, there are some fine chestnut trees, that bear well, to be found in California and southern Oregon, and the tree will doubtless do well in the Coast ranges where there is not too much lime in the soils. Chestnuts are now largely imported from southern Europe, especially from Italy. The wild chestnut trees in the Eastern states have for some time past been dying out from a fungous disease, which should be kept out of the Pacific Coast.

CHAPTER XXII

GARDEN VEGETABLES, FRUIT, AND FLOWERS

VEGETABLES grown in gardens on a small scale include many of the crops already mentioned as field crops, and which, when grown on the large scale for city markets or for canning, are called truck crops. As in the case of field crops, vegetables may be grown for their roots, stems, leaves, fruits, or seeds.

Of *leaf* crops we have in most gardens the lettuce, spinach, cabbage in many varieties; of *stem* crops, the asparagus, celery, and rhubarb; of *root* crops, the radish, potato, red beet, salsify, parsnip, carrot, and several others of less general use. Of the *seed* crops the various beans and peas are the most important. Of fruits which are not sweet we have the cucumber, the squash, the tomato, the egg plant.

Of sweet fruits we usually find in gardens the strawberry, raspberry, blackberry, currant, gooseberry, and melon.

LEAF VEGETABLES

Of vegetables grown for their leaves, the most familiar is probably *lettuce*, which has many wild relatives considered weeds, all with small blossoms, like those

of the lettuce itself. The sow thistle, much liked by stock, is common everywhere. The prickly lettuce, also quite common in California, is supposed by some to be the wild ancestor of our cultivated kind. When lettuce goes to seed it gets a bitterish taste like the wild lettuce, and, like the latter, produces a sleepy feeling when eaten.

The cabbage group of vegetables is the most widely used of leaf vegetables, especially in the form of head cabbage. Its numerous forms have been shown in figures 156 and 157, pages 268 and 269. The cabbage group is the most nutritious of leaf vegetables, and on that account is eaten very largely by the people of northern Europe. It is cooked in a great variety of ways, and is put up for winter use in large quantities in the form of "Sauerkraut."

For this purpose the heads of cabbage are cut into shreds by means of plane irons set in the face of a smooth bench, or sometimes by revolving cutters. The shredded cabbage is then well salted and packed in barrels or tubs, in which it undergoes a fermentation a good deal like that of cheese, getting a flavor much liked by Germans, Scandinavians, and Russians. "Sourcrout," as it is commonly spelled in English, is considered a very good food and very healthful.

Cauliflower has the most delicate flavor of the cabbage group. The part eaten is the young flower stems, which are gathered into a cheese-like mass inside of an outer basin or envelope of leaves, like those of ordinary cabbage. If left in the ground or replanted in spring, the cauliflower mass

FIG. 173. — Lettuce farm (State of Washington).

turns into a large number of flower stalks, with pretty, pale yellow flowers.

Brussels sprouts are small cabbage heads that have sprouted on the stem from buds, instead of one large head at the top.

Collard is the name given to a tall-stemmed kind of cabbage which does not form a head, but whose leaves grow all along the stem and are fed to stock, and also cooked by boiling for the table. It is a tall kind of "*Jersey kale.*"

Spinach is also a very common vegetable herb. It came to Europe from Persia or Mesopotamia, where it still grows wild. Unlike lettuce, it is always eaten boiled.

The leaves of many other plants, and sometimes the entire plants, are eaten as "greens" in different countries of the world; raw, sometimes as salad, sometimes cooked. "Mustard greens," "turnip greens," the young plants of the dandelion, various cresses, and a great number of other herbs are thus used.

STEM VEGETABLES [1]

Of vegetables of which the stems are used for the table, *asparagus* is probably the most widely known. Various kinds of asparagus grow wild on the shores of the Mediterranean. Among these is the ancestor of our cultivated kind. The stems of the wild asparagus, hardly as thick as a pencil, are very bitter, but yet are eaten in Spain and Italy. By cultivation in very rich soil the sweet, tender, thick-stemmed asparagus of our markets is obtained. The sprouts we eat are the

[1] This is not strictly correct, as leaf-stalks are here included.

flower-bearing stems, as in the case of cauliflower. But we must not cut them all off, for we then weaken the roots too much.

Asparagus for market is mostly grown in rich valley soils, in low and even peaty ground, as on the islands of the Lower Sacramento and San Joaquin Rivers in California. Asparagus beds are made by setting out roots obtained from the seeds of strong-growing stems. Asparagus can stand considerable alkali, and is benefited by the application of some common salt.

Celery is another stem vegetable, much grown in California, and in soil much like that for asparagus. The green leaf stems are bleached ("blanched") by heaping earth around them as they grow, so as to keep them in the dark (see page 119). Celery is said to be very wholesome. It is much grown in the peat lands of Orange County, California, for early shipment to the East.

Rhubarb (pieplant) is extensively grown for its leaf stems, which are quite acid from the same acid (oxalic) as sheep sorrel and sour dock. Rhubarb is a native of the mountainous regions of southern Asia, where it is grown, or gathered wild, for its yellow, bitter roots much used in medicine.

The **cardoon** or **chard** is doubtless the wild form of the true artichoke, which is so commonly seen in markets of California and southern Europe. Of the chard, however, it is the tender leaf stalks that are used in cooking, much like celery stalks when boiled. It is much liked and grown in southern Europe, which is doubtless its original home, as it still grows wild there. It is much esteemed in southern California and northern Mexico.

The **artichoke** differs from the cardoon in having rougher and harsher leaves, and larger flowers, or rather, flower heads. The thickened leaves (bracts) of the flower head are soft at the lower ends, and are eaten when boiled, as is also the upper end of the flower stem. The purple flower heads of the artichoke are very pretty when in bloom, and sometimes the plant is grown for ornament.

Another stem vegetable is the **kohlrabi,** which is a cabbage stem much swollen an inch or two above the ground (see page 269). It looks like a Swede turnip, but tastes more like cauliflower. (See figure.)

ROOT VEGETABLES

Of vegetables used for their roots, the *radish* is probably the most familiar.

Radishes resemble somewhat the common turnips, but are usually grown only on a small scale, to be eaten fresh. In California the garden radish has escaped from cultivation, and has become a very troublesome weed, with beautiful pink-and-white flowers in spring. With the yellow mustard bloom it makes the fields beautiful, but hard to keep clean. The roots become very hard and tough, and last several years, all the time bearing a great deal of seed. It is quite different from the weed radish of Europe, but its pods tend to become subdivided like those of the Old World weed.

Carrots are mostly a garden vegetable, but some large kinds are also grown in large quantities in fields for feeding cattle. Their cultivation is a good deal like that of beets.

So is that of the **parsnip,** which resembles the carrot; while the **salsify,** of which we eat the root, is a kind of sunflower with a pretty yellow bloom. The **chicory,** with a pretty blue flower, is grown for its root, which is used to color or to adulterate coffee.

The **onion** tribe, with its many kinds, is among the most anciently cultivated plants. This is especially true of the garlic, the common **onion,** and the **shalot,** all of which probably came from western and middle Asia to Europe on the West, and to China on the East. The intense flavor of **garlic** seems to have made it more particularly liked by southern people, while the onion and shalot have found more favor in northern countries. Cultivation has changed the small bulb of the wild onion (of the Kirghis Steppe) into the great Weathersfield onion, sometimes six inches wide and weighing a pound. The numerous small bulbs or "cloves" of garlic grow around the base of the parent stem, while of the shalot only the stems and leaves are used for flavoring.

Individuals and nations differ widely in their liking for these vegetables, some eating the onion bulbs and cloves of garlic raw, while others like only a slight flavoring.

Onions are mostly propagated from seed, but often from bulblets borne in place of flowers by some varieties. Garlic is partly sown as seed, partly grown from single "cloves." Shalots are grown from seed.

The **chive** is a small onion plant, about six inches high, which is found all over the world and is used for flavoring. Its native country is not known, and small kinds closely resembling it are found wild more or less all over the United States. These small wild onions are very unwelcome in pasture grounds, because they give their flavor to the milk of the cows, so that dairying has been abandoned in some regions where they grow in abundance.

FRUIT VEGETABLES (NOT SWEET)

Among cooking vegetables in which the fruit is the part eaten, the **tomato** is probably the most used in the United States. It is a native of Peru, but its fruit, when it is wild or has long escaped from cultivation, is a red berry not much larger than a marble. By cultivation it has been enormously enlarged. When first cultivated the fruit was flattish and full of green, hard walls, but these have now been done away with, so that our large tomatoes are much more soft and juicy than the small fruit of the wild plant.

The seed is sown in boxes, and the seedlings set out when a few inches high. The first flowers usually do not bear fruit, but fall off; later in the season most of them set. The leaves have a disagreeable scent, are sticky, and probably poisonous when eaten. Not over fifty years ago the fruit also was thought to be poisonous by some people. Tomatoes are now eaten all the world over; raw, cooked, or as sauce (catsup).

The **eggplant** (a native of southwestern Asia) is closely related to the tomato and potato, and has been long known, as it supplies food in almost desert regions.

On the Pacific Coast it is mostly of a purple tint, and of the size of a small melon. The smaller sizes are more peppery in taste than the larger ones, and on that account are liked best by some people.

The same is true of the **peppers,** of which the large "bell peppers" are a good salad or cooking vegetable. The smaller kinds, some of which are of the size of a marble only

(Tabasco peppers), or long, cylindrical pods, are very strongly peppery. The small kinds (Chiles or chillies) are those chiefly used by southern nations, and can be seen drying over the doors of country houses all over Mexico, Central and South America, and in southern Europe and Asia. Persons get used to eating these peppers very "hot" (as in the "Tabasco pepper sauce"). The red pepper is very much less injurious than the black and white peppers of India, which should be used only in great moderation. The peppers and eggplants are sown, set out, and grown, just like tomatoes.

Cucumber. The cucumber is one of the oldest known vegetables, having been cultivated in China for at least three thousand years. It is usually eaten unripe and raw, either as salad or pickle. Sometimes (as in Canada) it is eaten out of the hand like an apple, also cooked like squash. Raw cucumber is rather difficult to digest, though less so when pickled quite young, and the small kind, called gherkin, is often used for this purpose. Cucumber vines are allowed to run on the ground, thus forming circles six or eight feet across; therefore the plants must be grown at that distance apart.

Pumpkins and **squashes** are closely related plants, differing in size, shape, and the color and quality of their flesh, which in some is very sweet, in others almost tasteless, as in the early white squashes and the eight-sided one called vegetable marrow. The summer squashes, with yellow flesh, are quite sweet and well-flavored, as is also the pumpkin, from which pumpkin pies are made. This is also grown in large quantities in fields, as winter food for stock; mostly between rows of maize, where it makes most of its growth after the corn is harvested. Squash and pumpkin vines run much farther than cucumbers do, and have large, showy, yellow flowers.

Gourds of various kinds are often seen in gardens, where the long-necked kind is often grown for use as dippers or bottles. After they are quite ripe the inside is taken out, leaving the hard shell. The flesh of gourds is very bitter, so the shell must be soaked for some time to take out the bitterness before being used for cups or bottles.

Squashes, pumpkins, gourds, and melons all have two kinds of flowers. Some (the pistillate) have a little bulb below, that afterwards becomes the fruit. Others (the staminate) have only stamens and pollen, and form no fruit (see page 92).

SWEET GARDEN FRUITS

Of the sweet table-fruits commonly grown in gardens, the small or berry fruits — strawberries, raspberries, and blackberries — are the chief ones; also melons, and though not very sweet, currants, and less commonly, gooseberries.

Strawberries. Strawberries are found wild in Europe and Asia, as well as in America. The Old World strawberry is of course the one longest in cultivation. Then the Virginia strawberry was found in eastern North America; and finally the Chilian strawberry was found on the Pacific Coast, in California, Oregon, and Washington, as well as in Chile. In cultivation these three kinds have now become so mixed that it is hard to say from which of the wild ancestors the best of the cultivated kinds have come. They have been increased enormously in size and productiveness. But the large cultivated berries rarely are as sweet and high-flavored as the wild berries when well ripened. The cul-

Fig. 173 *a*. — Strawberry field.

tivated berries vary in shape, all the way from the "lady finger" to broad heartshape.

Strawberries are grown in rows (figure 173 *a*), two to three feet apart. When they are through with blooming and bearing, they put out runners that cast roots between the rows. By cutting off the stems we thus get rows of new plants for the next season. But by irrigating the old plants and cutting off the runners we can, in regions with mild winters, keep them bearing so as to get several crops from one set of plants. By planting early and late varieties we can have berries almost all the year.

Raspberries are of two chief kinds, red and black, with many varieties of each. The black raspberries (also called blackcap) are at home in America, while the red, with its varieties, the yellow and white, are from the Old World.

Raspberry bushes have a woody stem, but bear only once on the same wood; so that new woody shoots are sprouted every year, while the old canes die and should be cut away when through bearing. The red raspberries are propagated by layering, by cuttings, or by dividing the root clumps. The blackcaps have a habit of rooting at the tips of the stems and there forming good rooted plants. Delicious blackcaps and red *thimbleberries* are found wild in the woods of Oregon and Washington.

Blackberries grow wild all over the United States, preferably in limy black lands, where they grow very large and sweet. There are three chief wild kinds: (1) the *bush blackberry* of the Eastern states, of which there are many cultivated varieties; (2) the *dewberry*, which grows trailing on the ground and is very large, sweet, and aromatic; and (3) the *briar blackberry* of California and the country west of the Rocky Mountains generally.

Blackberries differ from raspberries in that they do not

come off from the green core. In California we have a hybrid called the *Logan berry,* which looks like a blackberry half ripe, and has the flavor of the red raspberry. It is a delicious fruit and specially good for preserving.

The **salmon berry** is a beautiful wild fruit of the lowlands in the coast region of Oregon and Washington. It looks like a very large raspberry; like it comes off the green core, and may be either red or yellow. But it lacks sweetness and flavor, which could doubtless be given it by hybridizing. It is not yet in cultivation.

Gooseberries and currants. Both these plants grow wild in Europe and North America. Many species are at home on the Pacific Coast. But none of these latter have as yet been improved by cultivation. The large red "cherry currant" of California is probably the finest fruit of its kind. The gooseberry is not much grown on this coast, but gooseberry pie is almost as much liked in the East as is pumpkin pie. The yellow-flowered black currant, a native of Missouri, has a strong "foxy" flavor, much liked by some persons. The California red-flowered currant, with scented leaves (which bears a gooseberry fruit), is a beautiful spring flower, growing in the cañons, and is much seen in gardens.

Melons. Other sweet fruits commonly seen in gardens are the *muskmelon* or cantaloupe, and the *watermelon.* The last named is known to grow wild in Africa. The muskmelon seems to be at home in southern Asia, where it has long been cultivated. Persia is noted for its muskmelons. There are a great many varieties, with flesh either green, yellow, or white, outside smooth or netted. Watermelons also may have either reddish or white flesh, and one kind ("pie melon") is not sweet and is only fed to cattle.

Melons also have two kinds of flowers, of which only one sort bears the fruit. They are grown in "hills" from eight

to ten or more feet apart. Sometimes manure is dug in two or more feet under each hill, producing a very rapid growth. Melons do not ripen in northern countries, but from the desert part of California (Coachella, Imperial) they are shipped East as early as May. In tropical countries the seeds of the watermelon are eaten as peanuts are with us.

FLOWER CULTURE

Owing to the great variety of climates found within it, the Pacific Slope has probably a greater variety of beautiful wild flowers than any other region. From early times California wild flowers have been carried to other countries as choice garden flowers. Thus the yellow and white native poppies, the baby-blue-eyes, the gilia, godetia, clarkia, eucharidium, collinsia, and many others that grow abundantly on the hills and in the valleys of California have become familiar garden flowers in the Eastern states and in Europe.

Of course, *all* garden flowers originally grew wild somewhere, but California seems to have supplied a larger number of valued cultivated flowers than any other country of similar extent. On the other hand, in California the various climates make it possible to grow out of doors probably a larger variety of the flowers of other countries than can be done anywhere else.

Of course, we must not try to grow flowers, any more than other crops, in places where the climate (heat, cold, moisture of the air, dryness, etc.) is too different from their native

countries. So, for instance, most of the wild flowers of the Middle West, where they have moist air and frequent rains, will not do well in California, no matter how much they may be watered. But they will do well in western Oregon and Washington, where there is moist air and plenty of rain in summer. And the native plants of these regions, such as the salmon berry, salal, linnæa, vancouveria, bilberry, and others of the moist woods, will not grow in California, except in Del Norte, Trinity, and parts of Siskiyou Counties, where there are also summer rains.

As the beauty and commercial value of flowers depends so greatly upon their perfect development, they should always be grown in rich, loamy soil with plenty of humus, which must be kept well cultivated and watered. Stable manure well rotted is the best fertilizer for nearly all flowers. This is specially true of roses. "Rose land," on which the native wild rose grows in dense thickets for many miles in Washington and Montana, is considered the best land of the region. It contains much lime and humus.

Flower seeds are frequently very small, and must therefore be sown on a well-mellowed surface, and only very lightly covered with fine soil, which must be kept moist (best by covering with light shingles). But these must be taken away so soon as the seeds have sprouted, when the ground may merely be kept shaded from the sun. It is often best to sow the small seeds in boxes kept indoors, and then set out the small seedlings where wanted. Many people sow flower seeds as they do corn or radishes, covering them an inch or more deep. They are then usually not seen

again, and then the seedsman is blamed for having sold poor seed.

Cut flowers can be made to keep fresh many days by putting them in fresh water every day, each time cutting off a little piece of the end of the stem, after rinsing or washing it to take off the bacteria. A few drops of washing ammonia in the vase water is also a great help.

AROMATIC PLANTS AND SEEDS

A large number of plants are grown for the odors yielded by their leaves. Among these are such well-known herbs as the garden sage, the peppermint, sweet basil, marjoram, lavender, rosemary, thyme, catmint, catnip, and many others belonging to the mint family, with two-lipped flowers. Many of them grow wild on the Pacific Coast. Of the sunflower family we have the camomile, of which the flowers, like the leaves of the others mentioned, are often used for making teas for sick persons. It is pleasant to have these odorous herbs about the house and garden, and they also serve for seasoning in cooking. From some of them, valuable essences are made.

Then there are many plants bearing aromatic seeds, such as caraway, anise, coriander, celery, parsley, fennel, and others, belonging to the carrot family.

All these grow very well in California, and many as far north as Washington.

Perfumes, the agreeable odors we use in handkerchiefs, are largely made from flowers, such as those of oranges and lemons, roses, heliotropes, etc., and are procured from them in various ways. Rose and orange-flower waters are made by driving steam through the flowers; but these must be grown in a hot climate, not on the coast, where the odors are faint and inferior.

It is a great art to make from these aromatic essences just the right mixtures for cologne water, violet water, and others, in which these essences are dissolved in alcohol. The finest of the flower perfumes are not made with steam, but by catching the odors in pure fat, spread on glass panes in close boxes, to which are constantly added fresh supplies of flowers, such as violets and heliotrope. You can make delicious pomatum in this way, or the odor can be drawn out of the fat by pure, weak alcohol, which can then be used for handkerchief perfumes.

CHAPTER XXIII

FORESTRY

EVERY year property worth millions is destroyed and hundreds of lives lost by floods. This comes largely from cutting down our forests. The forests prevent floods in a very simple way. The ground in the forest is covered with leaves, and when rain falls they soak it up like a sponge. Underneath the leaves there is soft leaf mold, which also acts like a sponge. Underneath this again are the spongy roots of the trees, which also help to hold water. So the forest acts like a giant sponge to catch the rain as it falls and hold it fast.

All summer long it is moist and cool in the forest, and when you dig down into the soil you find that it is full of moisture. The water trickles slowly into the little brooks and streams, so that they flow all summer long and do not dry up. But if there is no forest to hold it back, the rain runs off the bare soil, floods the lowlands, and escapes to the ocean. Then the streams soon cease to flow, the land dries up, and crops fail.

Figure 175 shows what has happened in China where the forest has been cut away and the land left bare and exposed to the action of the rains. All of these hills

FIG. 174. — The melting snows keep the forests green, and they in turn hold back the water. This prevents floods and keeps the streams from drying up in summer.

Fig. 175. — The result of cutting down the forests. A century ago these hills were covered with splendid forests and gave rich crops of lumber. Now only bare rock remains.

(an area of two hundred square miles) were covered with forests and gave rich crops of lumber a century ago. Practically all the soil has been washed away, leaving only bare rock, on which no soil is now forming, because of the heavy rains.

FIG. 176. — This forest has been burned twice. No young trees are left to make a new forest.

Nothing can hurt the farmer more than to have the forests destroyed. If the lumberman would cut only the old trees, leaving the younger ones to grow, it would not hurt the forest. Then the forest would last forever and would yield a good crop of lumber every year. But the lumberman usually prefers to cut the forest down all at once and destroy it, because he can make

more money in that way. He does not bother himself about how it affects the farmer, nor about what will happen to the country when the forests are all gone.

The only way to save the forests is to have the government look after them. Every one should help to bring this about. Then we shall have all the lumber we need without destroying our forests.

Every year great stretches of forest are destroyed by fires which sweep over them (figure 176). Sometimes these are started on purpose, sometimes by carelessness. They can and ought to be prevented. The best way to stop fires is to have broad lanes cut through the forest so that when the fire comes to one of them it may be stopped. Men must be employed to watch the forest, so as to stop the fire before it can get a good start.

Private owners of forests should be compelled by law to take care of their forests, so that fires cannot start there, for such fires may quickly spread over a large district.

Grazing by animals, especially by sheep, must be regulated so as to prevent killing the young trees.

HOW TREES GROW

When you look at a stump, you see the rings of the wood, one of which is usually made each year. You can tell by the thickness of the ring whether the tree

grew fast or slow. If you look at the rings near the center, you will notice that they are thicker than those near the edge. This shows that at first the young

FIG. 177.—The Sir Joseph Hooker oak, Chico, California. (Notice the size of the tree as compared with that of the horse and buggy in front of it.)

tree grows rapidly. But it can, as a rule, keep this up for only a few years. Then it begins to grow more slowly, and by and by stops growing. Then it should be cut down to make room for young trees. The small branches should not be left to feed forest fires, but should be burned on the spot. Lumbermen should be compelled by law to do this cleaning up.

FIG. 178. — A forest of Douglass fir (Oregon pine) and giant arbor vitæ (State of Washington).

When a tree stands by itself, its branches spread out, and even the lower ones are able to grow (figure 177). The branches of a tree cannot grow without light. In a forest only those at the top of the tree get light enough to grow. The lower ones all die off, leaving a straight clean trunk (figures 178 and 179) which gives boards without knots. This is called self-pruning.

In the forest we see that *the trees not only struggle with each other, but they also help each other as well.* The different branches of a tree struggle together for light, yet they all help each other. Each tree spreads out its branches and tries to get all the light it can for itself, and the young trees beneath it may suffer, because it takes so much light away from them. But it is only by growing together that the trees of the forest are able to keep the ground moist enough so that all may grow. And were it not for the shade of the older trees, many of the young trees would be killed by the strong sunlight.

Nothing is more interesting to study than the growth of a tree. A tree writes the story of its life as it goes along, and when you have learned how to read it, you will know just what it has done, as well as what it has tried to do and failed. If you wish to know how this may be done, read Bailey's "Lessons with Plants," pages 25 to 77.

Many trees grow well from seed, and it is very well

FIG. 179. — A Sequoia grove.

worth while to plant them.[1] To find out what kinds of trees are best adapted to different conditions is also worth while. *There should be trees around every home, and along every street and road.*

STUDY OF WOOD

The study of wood is also very interesting. Look at the boards in the woodwork of a room. Which way does the grain run? This will tell you how the board stood in the tree. When the saw goes through the center of the tree, we get a board with straight grain. Otherwise we get a board with curved grain. Such a board is handsome when smooth, but very apt to splinter.

The place where a branch or root joins the trunk is called the crotch. At such places we find a peculiar sort of grain, as shown in figure 180. Saw open a crotch or stump, and smooth the surface with a plane or chisel. Notice that the part of the grain which is dotted in the figure is end wood (that is, the grain is cut across instead of lengthwise). For this reason, and also because the grain is often bent or twisted, crotch and stump wood is beautifully figured and is highly prized by cabinet makers. It is often used as veneer.

[1] Those who have difficulty in getting tree seeds or in making them grow should write to the Monterey Tree-growing Club, Monterey, Cal., for free seeds and information.

There are two reasons why the grain is bent or twisted at the crotch. One is that the grain must bend around the branch. Another is that the wood has less space to grow in each year as the crotch fills up. As will be seen by the figure, the wood had during the first year a great deal more space for growth than during the last year. As it cannot spread out, it tends to grow thicker in the crotch, and it will be noticed that the annual rings are thicker here than elsewhere. It also tends to form a hump, as shown in the figure. Beneath the branch the same thing is seen, though to a less extent. For the same reason any bend or hollow tends to fill up, and so both trunk and branches get straighter as they grow older. The grain in such places is often wavy, as seen in curly redwood.

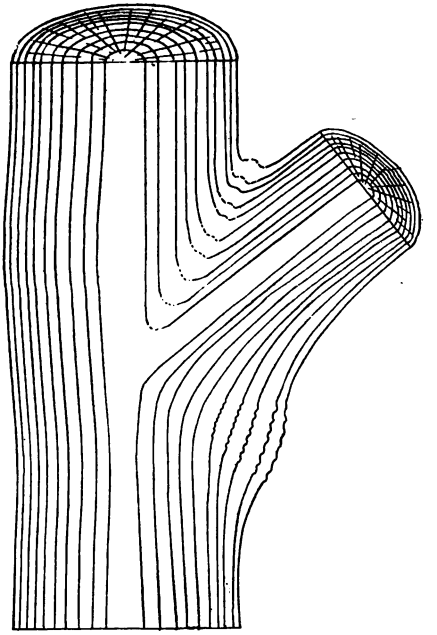

FIG. 180. — A branch split open to show how the grain of the wood runs.

Every branch starts at the center of the tree; no matter how old it is, you can always follow it clear in to the center when you split the trunk open. Sometimes you find that it sends out small branches inside the trunk. This makes the kind of wood seen in bird's-eye maple and curly redwood.

Every visit to the wood pile teaches something new and interesting. Notice how the bark looks under each small branch; can you explain how rings are formed which you see on the outside of the bark? What happens to small branches which are broken off close to the trunk? Why does a knot in a board fall out and leave a knothole?

Each kind of wood has its use. Find out the uses of the common woods and why they are so used.

What causes the warping of wood? How can it be prevented? If a dry board is placed in water, does it swell just as much with the grain as across the grain? Draw a square ten inches each way on a dry board and keep it under water for a week; then measure the square. How much larger is it? Is it still a square?

There is much good information about trees and forests in Pinchot's "Primer of Forestry," Roth's "First Book of Forestry," and Hodge's "Nature Study and Life," Chapters 22 and 23.

CHAPTER XXIV

NEEDS OF THE ANIMAL: USE OF FOOD BY MAN AND OTHER ANIMALS

To Teachers. — Certain fundamental principles of animal physiology are, as a rule, best approached through the study of the human body, as treated in Chapters 24, 25, and 26. If the pupil already has a sound knowledge of these matters, they may be omitted, or only such parts taken up as apply to the farm animals. The directions for the care of the health may be left to the discretion of the teacher.

So far our study has been mostly about plants. We will now try to learn something about how animals (including man) digest their food, breathe, and move about, as well as how the chief organs of their bodies act and how they should be cared for. We shall then study the different kinds of farm animals.

What do animals need? When we think over our own needs, we see that they are the same as those of the plant: air, water, food, light, and warmth. These are the needs of all animals. Each need brings a problem to solve. The animal that learns how to get these things in the best and easiest way will get ahead of the rest in the struggle for life that always goes on.

How long can animals live without supplying these

needs? We can live without air for only a few minutes, without water for about a week, without food for over a month. We can get along without light for a good while, but we cannot get along without warmth even for a moment. To keep up this warmth, food must be burned in the body all the time, without stopping even for an instant. And so the first and greatest problem is to get the best sort of food and plenty of it. The cold-blooded animals such as fishes, frogs, snakes, and worms do not need so much warmth. A frog may even be frozen for a time in a cake of ice without injury.

For what is food needed? We have seen (page 84) in what way food is used in the plant. It is (1) burned up, (2) built up into the growing body, (3) stored up for future use. Just so with the animal. The animal burns up a much greater part of its food to keep warm (except in the case of cold-blooded animals) than the plant does.

What are the kinds of food? First, protein; second, fats, including oils; third, sugar and starch (in the process of digestion starch is changed into a kind of sugar, which is then taken up by the body).

What kind of food is best for burning in the body, in order to keep warm? In cold weather we always eat more fat; this is good, for fat gives out a great deal of heat when it burns. So do sugar and starch. Protein gives out only about half as much heat as fat or sugar. Fats and sugars are known as "heat-making foods."

What kind of food builds up the body? Protein is the principal one, and so growing boys and girls should eat plenty of this. Athletes in training eat a great deal of meat, because they think it makes muscle better than any other kind of food. Protein is known as "muscle-making food."

What kind of food is stored up? Principally fat. If we eat and digest more food than we need for fuel, we increase in weight. A part of this increase may be in the form of protein, etc., but after the period of growth is past the increase is principally fat.

How much food do we need? If we know how much work a man does every day, we can tell just how much food will give him the strength to do this work. In America a man doing average work needs about a quarter of a pound of muscle-making food and a pound and a quarter of heat-making food each day. This is the weight of the food after it has been dried. Before it is dried this would weigh three or four pounds, and this is really about all a man needs. Many people who do not get enough exercise eat a great deal more than they should.

Many foods which we eat are mostly water, as, for example, milk and most vegetables. A pint of milk (which weighs about a pound) contains very much less food than a pound of sugar.

Mixed diet. But we cannot live on sugar alone, because it does not contain any muscle-making food

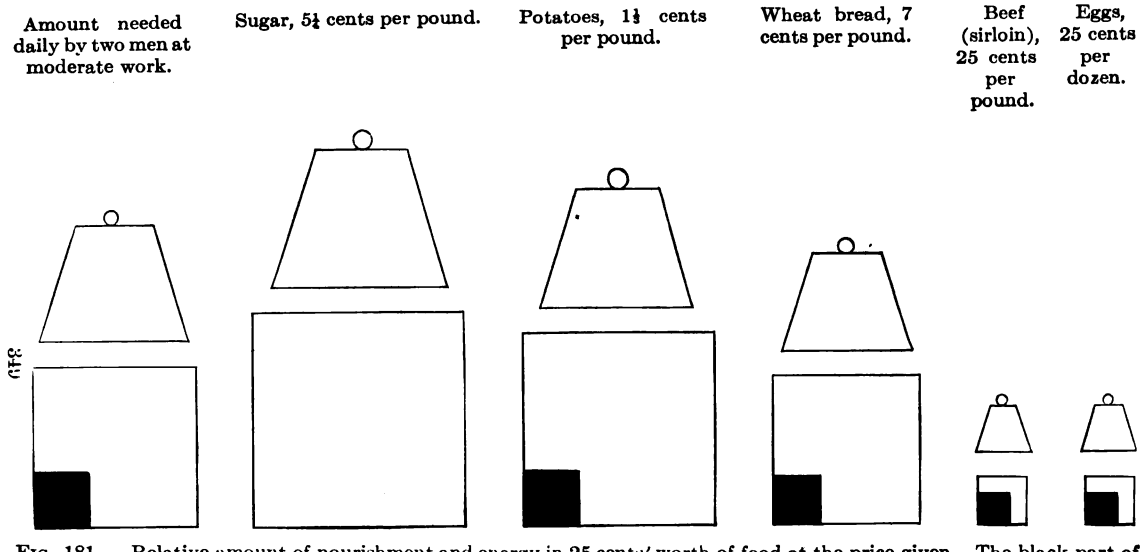

FIG. 181. — Relative amount of nourishment and energy in 25 cents' worth of food at the price given. The black part of each square shows the amount of *muscle-making food* (protein). The white part of each square shows the amount of *heat-making food* (sugar, starch, fat). Above is shown the relative size of the weight that could be lifted to a given height with the energy in the food.

(protein). In figure 181 the muscle-making food is shown in black in each square; the heat-making food is shown in white. You see that milk contains both kinds of food. Beef, eggs, and beans contain a great deal of muscle-making food, as you may see from the large black part of the squares in the figure.

In order to keep well and strong we must eat a good many different kinds of food, such as meat, fish, vegetables, fruit, and sweets, and especially *of the kinds we enjoy most.* Then we should drink plenty of pure water and take plenty of exercise in the fresh air to make our food digest.

How to cook food. Cooking not only makes food taste better, but helps to digest it. A lump of dough is partly digested while it is being baked into bread. Part of it is changed to sugar, and this makes the crust taste sweet. In the body the same thing happens. The starch is partly changed to sugar in digestion. The brown sticky substance of the crust is also made from the starch by partly digesting it.

We make dough by mixing flour with water and adding sugar, salt, and sometimes butter or milk. We also add yeast or baking powder, and let the dough stand in a warm place. Bubbles of gas (carbon dioxide) begin to rise and lift up the dough into a light spongy mass. If the dough contains enough protein, it will be tough and hold the gas bubbles even when they grow larger in the heat of the oven. But if there is too

little gluten, the bubbles will rise out of the dough and escape into the air and the dough will fall. In order to get enough gluten in the flour we must have the right kind of wheat (see page 275).

The heat of the oven makes protein firm and hard. When we *cook eggs* the white of the egg, which is made of protein, gets firm and hard; we say that it coagulates. It is very easy to cook it in such a way that it gets too hard. The best way to have it tender you may see by making the following experiment.

First, put some eggs into cold water and heat to boiling, then take the eggs out.

Second, drop them into boiling water and take them out after three or four minutes.

Third, drop them into boiling water (three fourths pint to each egg), then set the pot on the back of the stove and allow it to stand about ten minutes.

The first and last methods cook at a *low temperature*, and give very much more tender and easily digested egg substance than the method of boiling, at a higher temperature.

Cooking meat. A high temperature makes the meat tough and stringy. A low temperature makes it tender and easily digested. This must be so, for eggs and meat consist largely of the same kind of substance — protein.

How to cook meat. If we first expose the meat to strong heat just long enough to brown (coagulate) the

outside, we may then cook it as long as necessary at a low temperature without danger that the juices and flavoring matter will escape. But if we do not first brown (coagulate) the outside, the meat becomes dry and flavorless. "Basting" a roast by pouring the gravy on it while roasting helps to coagulate the outside. Since fish cannot be so well treated in this way, we may immerse it completely in hot fat. The fat keeps the juices from coming out, and it does not itself go in to any extent.

Frying is generally the poorest way of cooking, because it usually allows the fat to go in, the juices to come out, and the temperature to get too high. Together with hasty eating, it is to a great extent the cause of our national evil of indigestion.

Beef tea and broth. Meat also contains *albumin*, a substance similar to white of egg. And when we make beef tea for sick persons, we mince the lean meat fine, and then put it in warm water (150° F.) for two hours. The water extracts the albumin substance, as well as the flavors of the meat, and so we get a very nourishing drink. But if we boil this beef tea, the albumin is boiled hard (coagulated), and then the fluid left behind is simply broth, which stimulates, but does not nourish. This is what we get in boiling meat for soup.

Try the experiment of putting some chopped meat in water for half an hour without heating it. How does the taste of this meat after half an hour compare

with that of meat which has been dropped in boiling water, allowed to boil a few moments, and then allowed to stand half an hour? Is a low or high temperature best for extracting the flavor? Which method extracts the most albumin from the meat? Test this by boiling the water in which the meat has been standing and thus coagulating the albumin.

Meat should be boiled only when the liquid is to be saved and used as in soups and stews. These are very economical, because they make use of every bit of nourishment in the food, and can be made of bones and small pieces which would otherwise be thrown away. If these small pieces are browned in the frying pan (especially with a little flour, butter, or olive oil) before being cooked in the stew, its flavor can be made delicious. It is just in the preparation of good soups, gravies, and stews that the people of Europe greatly surpass us, and are able to live well on what many an American family throws away. In America the poorest families usually waste most.

Economy in food. Figure 181 shows the relative amount of actual nourishment and energy in twenty-five cents' worth of food as purchased in the market at the prices given. We see that for twenty-five cents we get about eleven times as much energy in the form of wheat bread as in the form of beef or eggs. There is also given the amount of food and energy needed daily by a man at moderate work. We see from this that

twenty-five cents' worth of wheat bread will supply his needs for a day.

Examination of school children in New York City by doctors shows that over one half of them are poorly nourished. This is not so much because the parents are poor, as because they are ignorant, careless, or wasteful. They waste by buying food which fails to give the best nourishment, and waste much more in preparing it. Then their ignorance of the laws of digestion and exercise, and of the need of fresh air, leads to waste in the body and to ill health. This does even more harm during the period of growth than it would later in life.

Feeding of farm animals. What we have learned applies also to feeding animals. The choice of food is important, and likewise its preparation. This may include, in some cases, warming or cooking the food. By looking at "feeding tables," which tell how much muscle-making and heat-making food is found in hay, green fodder, and so on, the farmer can tell how much of these to feed daily. But he must take into account the cost, the supply he has on hand and its keeping qualities, the value of the manure produced from it, as well as other things.

What becomes of the food after it enters the body? We know that plants can take up only liquid food (page 10). Just so with the animal. All the food must be made liquid before it can be taken up and used by

the body. *The process of making food liquid is called digestion.* Let us see how some simple food, such as wheat, is digested or made liquid in the body.

If you chew grains of wheat, they soon begin to taste sweet, because some of the starch of the wheat has been changed into sugar. The saliva of the mouth contains a substance which has the power of helping to change starch into sugar. The sugar dissolves or becomes liquid in the water of the mouth. *Substances which have the power to make foods liquid are called ferments,* and they are of the very greatest importance to all living things, both plants and animals.

After chewing the wheat a little longer a white gummy substance remains. This substance is gluten (protein), the muscle-making part of the wheat (see page 273). The saliva softens this, but cannot make it liquid. When it is swallowed, it passes down through the gullet into the stomach (which is merely a pear-shaped sac, holding about three pints when moderately filled). By its motion the stomach churns the food and mixes it with a ferment (called pepsin) which helps to make protein liquid. The pepsin, together with acid and other substances secreted by the stomach, forms the gastric juice.

The fat of the wheat is not digested in the mouth or stomach, but passes unchanged into the small intestine. Into this the pancreas, or sweetbread (a tongue-shaped organ about six inches long, lying close to the stomach),

pours a juice which not only digests fats, but also any albumin and starch which has not already been made liquid. Now all the food is in liquid form ready to be taken up into the blood.

How is the liquid food absorbed? We have seen (page 12) that the plant must have a large surface to absorb its liquid food, and this surface is greatly increased by small hairlike bodies (the root hairs). It is much the same with the animal. A large surface is made by the great length of the intestine. The small intestine in man is over twenty feet long; this surface is increased by ridges on the inside of the tube and furthermore by hairlike bodies so thickly placed that they give the surface the appearance of velvet, as you can easily see, if you put a piece of the small intestine of a sheep in water.

From the small intestine, the food passes into the large intestine, which in man is about six feet long. Here the last of the liquid food is absorbed, and the part which has not been made liquid then leaves the body.

How other animals digest food. The digestive system of birds differs from ours, because birds have no teeth. When a chicken is being dressed, you may easily see all the digestive apparatus. The food passes down the throat into a sort of sac called the *crop*, in which it becomes softened, and then it goes into the stomach, the hinder part of which is called the gizzard. The

motion of this part of the stomach churns and grinds the food. The bird swallows small stones which greatly help in this process. From the gizzard the food passes directly into the intestine (see figure 182).

Animals such as cattle and sheep, which live entirely on grass, have to eat very much more food than those which live on flesh. They eat large amounts of grass without stopping to chew it thoroughly. Before reaching the

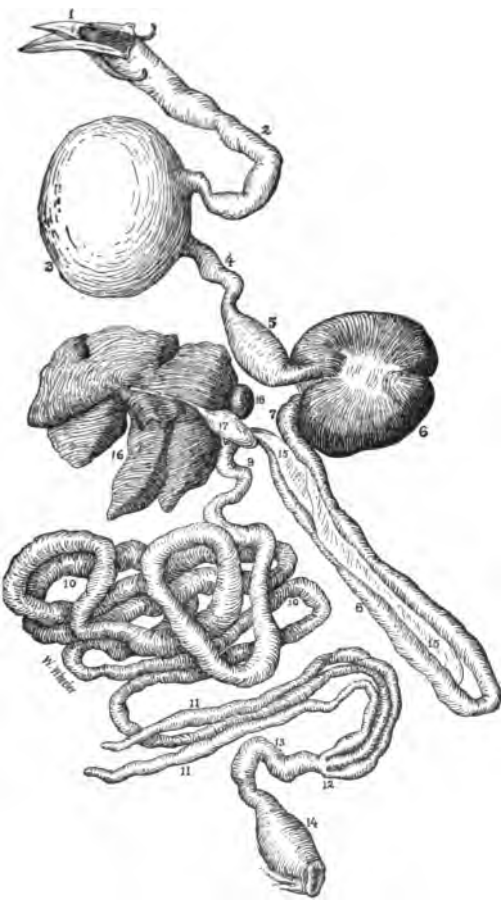

FIG. 182. — Digestive apparatus of a fowl: (1) tongue, (3) crop, (6) gizzard, (10) small intestine, (15) pancreas, (16) liver, (17) gall bladder, (18) spleen.

stomach the food passes through three large sacs which are to be looked upon as storage places similar to the crop of birds. From these the food is returned to the mouth to be thoroughly chewed ("chewing the cud") before going into the real stomach and the intestine, in both of which digestion takes place (see figure 183).

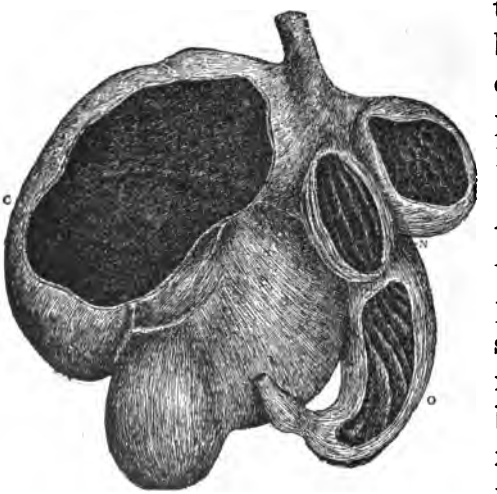

FIG. 183. Stomach of a sheep cut open.

As few of us take time enough to chew our food properly, we sometimes try to make up for this by cutting the food into fine pieces or otherwise preparing it before eating it. But it is impossible for anything to take the place of chewing the food. A part of the effect of chewing we can get by softening the food artificially, but the most important effect of chewing is to cause a flow of the digestive juices, and *to put us in the right condition for digestion.* For this reason we *cannot have the best digestion without long and thorough chewing of our food.*

By cutting up the stomach of an animal and pouring glycerin on it, we can extract the ferments or digestive juices. In the first place we may use these to partly digest our food before we eat it (predigested foods). Second, we may take them in small doses to help our own digestion. In general these digestives should be left to sick people and given under a doctor's direction. Their use easily leads to the habit of depending on them.

The best aid to digestion is exercise in fresh air. People who live indoors find their digestive troubles disappear as soon as they begin to live an outdoor life. If we neglect exercise too long, digestive troubles become chronic. The only safe rule is to set aside a part of every day for exercise.

The movement of food through the body must not be stopped or clogged. It is very important to avoid constipation. It is easily prevented by eating plenty of fruit and vegetables (as well as bread made of whole wheat or rye), by drinking plenty of water, and by exercise of the waist muscles, as in digging, hoeing, or sawing wood.

Those who take plenty of exercise need, as a rule, to pay very little attention to what they eat, but people living largely indoors must eat less, especially of meat, and should in general be careful of their diet.

Nothing upsets the digestion so quickly as the use of alcoholic drinks. No one should use alcohol during

the years of growth. Many patent medicines contain more alcohol than is found in whisky.

Lack of sleep, worry, overwork of brain, or muscles (as often happens in training for athletics), eating between meals, working just before or after meals, all disturb digestion more or less. When the digestion is seriously disturbed, rest, eat little, and then only of easily digested foods, such as toast, milk, soft-boiled eggs, and take all food slowly so as to mix it well with saliva before swallowing.

Good digestion means the highest efficiency of mind and body; digestive troubles cannot be neglected without danger of becoming chronic.

CHAPTER XXV

BREATHING

Why is it necessary to breathe? We know that food must be burned all the time in the body and that without air (oxygen) any burning soon stops. Plants get air through openings in the leaves and stem, insects get it through small openings along their sides, while the higher animals take air into the body through the nose and mouth. We know that a man can live only a few minutes without air.

How is air taken into the body? It is much better to breathe through the nose, because the hairs inside the nose strain out a great many of the dust and disease germs in the air, and the air is better warmed when taken in through the nose than through the mouth. Passing through the nose into the throat, the air comes to the "Adam's apple" (larynx), which is really the enlarged end of the windpipe. The air passes into this by an opening which is closed by a sort of trapdoor whenever food is being swallowed. Put your finger to your throat as you swallow, and you will feel your Adam's apple rising up to close the trapdoor. In this way food is kept out of the windpipe. We all know what happens when "food goes down the wrong way."

The sound we make in speaking or singing is caused by the air in passing over the membranes of the larynx, and thus setting them in motion.

The air passes down through the windpipe into the lungs (figure 184). Get from the butcher the windpipe and lungs of a sheep, calf, or hen, and see how they are made. The lungs are very soft and spongy. Blow them up by means of a tube fitted into the windpipe (or opening of the larynx): how much air do they hold when blown up?

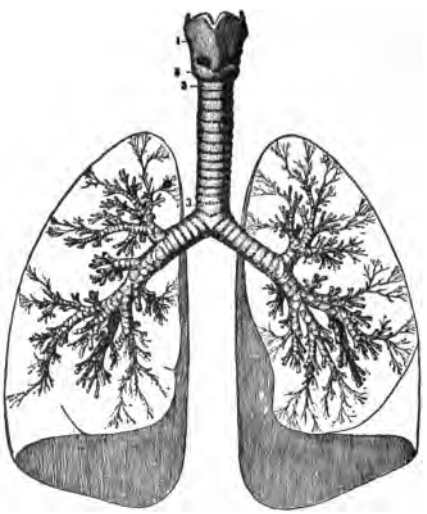

FIG. 184. — Windpipe and lungs.

Why does the air enter? We can best understand this by making the apparatus shown in figure 185. A cork or piece of wood is fitted into the end of a lamp chimney, and through this passes a tube of glass or metal, to the end of which a toy balloon or cat's lung is tightly tied (the tube must be fitted into the windpipe or larynx). At the other end of the chimney is tied a sheet of thin rubber (such as dentists use), to folds of

which two strings are tied. Thrust this down so as to take up as much room as possible inside the chimney; then put the stopper in the other end and make it air-tight (by means of sealing wax, grafting wax, or paraffin). Now draw the strings downward. This increases the space inside the chimney, and air rushes in to fill it. Why? The lung or balloon is thus blown up.

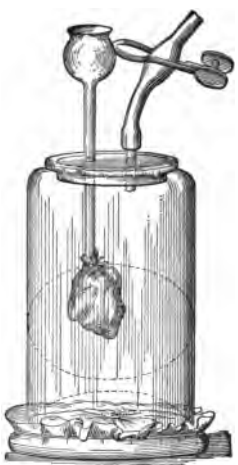

FIG. 185. — Apparatus to illustrate inflation of lungs.

It is just so that the lungs are blown up in breathing; but what corresponds to the sheet of rubber? Breathe out as much as you can, run a tape line around the chest, then breathe in as much as you can. How many more inches of tape does it now take to go around your chest? This is your chest expansion, and you should increase it in every way you can.

At the same time place your hand on the abdomen and feel how the diaphragm comes down and forces the abdomen out. The motion of the chest and diaphragm corresponds to the motion of the sheet of rubber. This motion is brought about by the action of certain muscles. The diaphragm, as is shown, forms the bottom of the space in which the lungs lie; this space is called the chest cavity. It contains the heart as well as the lungs;

the stomach, intestines, liver, and kidneys lie below the diaphragm.

What becomes of the air after it enters the lungs? The windpipe divides into finer and finer branches (bronchial tubes); the very finest of these end into little air sacs with very thin walls in which are very fine tubes. The blood in these tubes take up the oxygen from the air sacs, just as the cells of the leaf take it up from the air in the air chambers of the leaf. At the same time that the blood takes up oxygen from the air, it gets rid of carbon dioxide by giving it off and letting it escape into the air sacs. When the breath is blown into limewater it turns the limewater milky from the carbon dioxide in it.

What is the blood? Ask the butcher to get you some blood. At first it is liquid, but it soon becomes like jelly. This is due to a protein (fibrin) in the blood which coagulates in the same way that white of egg does when heated (see page 351). This is why a wound stops bleeding; were it not so, we might bleed to death from a pin prick.

The red color is due to very small disk-shaped bodies, the red corpuscles. It is these which take up the oxygen and carry it to all parts of the body, and give it up to the parts which need it.

There are also white corpuscles in the blood. Whenever a wound is made these white corpuscles gather at the spot, and it is thought that they attack and devour

any germs which may enter the wound. When the white corpuscles are killed by the germs or in any other way, they form pus.

The pale transparent liquid which separates from the blood on standing is called the *serum*. It is this which fills a blister. It contains liquid food such as is taken up from the intestine during digestion. The serum goes all over the body, supplying both food and water where they are needed. In this way it becomes poor in food and water, and then the sensations of hunger and thirst tell us that we need to eat and drink to renew the supply.

How is the blood changed in the lungs? If we put a little fresh blood in a bottle with plenty of air, cork it, and shake vigorously, it will turn a bright color, because it takes up oxygen from the air. It is the same way in the lungs; the blood entering the lungs is dark in color because it is poor in oxygen. In the air sacs it takes up oxygen and becomes bright in color; thence it goes to the heart and is pumped all over the body and gives up its oxygen wherever it is needed, and thus it makes possible the burning which goes on everywhere in the body. It was thought at one time that all the burning was done in the lungs, but this cannot be so, for the lungs are no warmer than any other part of the body.

The blood not only carries fuel (food) to be burned, but also the air (oxygen) to make it burn, and the burn-

ing goes on all over the body. Every part of the body burns what it needs to get energy to do its work and gives off the carbon dioxide formed in burning (also other poisonous and waste products) to the blood. The blood then goes back to the lungs to be purified by contact with the air.

The burning does not take place in the blood itself, but in the muscles, nerves, and other organs when they are at work.

Importance of deep breathing. Nothing helps so much to make us well and strong as deep breathing. To learn this is of the highest importance. *The breathing muscles should be trained as much or more than any others.* Fast walking, hill climbing, and running train these muscles. As many times a day as you can (whether you are indoors or outdoors), take a deep breath and hold it while you count ten. While holding the breath, bend back the head and stretch the arms. · In this way you will rapidly increase the size of the chest and the chest expansion, and you will increase your vitality and endurance. Short, quick breathing brings fresh air to the upper part of the lungs only. Tight clothing or lacing or anything which interferes with deep breathing is very injurious.

Without deep breathing the lungs do not get expanded by the air, and when we begin to run and take more air into the lungs it at first gives us an uncom-

fortable feeling of being "winded." After a little we get used to it, and thus get our "second wind."

Deep breathing wards off colds and many diseases of the lungs and other organs.

All persons who breathe through the mouth, or have a tendency to do so, should be examined for growths (adenoids) which stop up the passage of the nose and throat, and so hinder breathing. The removal of such growths sometimes transforms a dull boy into a bright one, for without a good air supply both vital and mental processes are slow and sluggish.

Importance of pure air. Out-of-door air is the only pure air, and we should spend every minute possible in the open air. Sleep in the open air if possible; next best is sleeping with the head partly out of the window when it is not too cold. This has cured many a consumptive. At least have some windows in the bedroom open. The cold air does no harm, but only good, so long as only the head is exposed to it: exposure of the body to cold draughts is dangerous.

Every schoolroom, church, theater, or public hall should be ventilated by means of fans and blowers which send currents of air (of the proper temperature) through it. Furnace heat for homes is far better than steam or hot water, because it provides a constant supply of fresh air, which should be filtered through cloth as it comes into the furnace. There should be some place for the air to escape, and for this purpose a

strip may be made (two inches wide) and fitted to the bottom of the window. The lower sash is pulled down on this, leaving a little space between the upper and lower sash through which air may pass in and out. An open fire provides splendid ventilation. On the other hand, the use of coal-oil stoves and gas stoves without chimney connection is very bad. Water heaters of this sort in bath rooms are responsible for many deaths by suffocation.

When people are shut up in a room without ventilation, breathing each other's breath, they soon grow sleepy, and, if they cannot escape, may become unconscious and may finally die.

Care of the breathing organs. When the surface of the body is suddenly chilled, the blood rushes from the surface to the internal organs and settles there, producing what we call an inflammation; in this bacteria play a large part. If this happens in the nose, we call it a head cold; in the throat, a sore throat; in the bronchial tubes, bronchitis; in the air sacs of the lungs, pneumonia; in the membranes which cover the lungs and line the chest cavity, pleurisy. In the latter disease the membranes stick together, and the movement of the lungs in breathing causes intense pain. Diphtheria and membranous croup are due to the growth of bacteria in the throat.

Consumption, the "great white plague," which kills more people than any other disease, could be entirely

avoided by proper care. It is caused by germs which are taken into the lungs with the air, and there grow and produce poisonous substances (toxins). When the system is "run down," and especially when the lungs are inflamed, they grow very rapidly.

One who has consumption should never spit except into a handkerchief or paper (which can afterward be disinfected or burned), because the sputum soon dries, and the germs are blown about in the air.

The ordinary schoolroom, church, or other public place is a perfect hotbed of these and other germs, because of the methods of sweeping and dusting. The proper method is described on page 256. *Nothing can be more unsanitary than a carpet,* for you cannot get the germs out of it by sweeping. Rugs which can be taken outside and beaten are safe and sanitary.

Treatment of drowned persons. Lay the patient face down, clasp your hands about his waist, and lift so that the water can run out of the lungs and windpipe. If he breathes, put cold water on the face and slap the chest vigorously. If he does not breathe, turn him on his back, place a rolled coat under his shoulders, open his mouth, and draw out his tongue. Grasp his arms at the elbows and pull them upward and parallel to each other, until they come to lie above his head: in this way air is drawn into the lungs. Now pull the elbows downward and press them against the chest; in this way air is forced out of the lungs. Keep this

up at about your own rate of breathing for several hours, if necessary, before giving up hope.

Persons overcome by gas or foul air should be treated in the same way.

Care of animals. Animals suffer from colds and from impure air in the same way as people, and it is not only humane but good business policy to provide them warm and comfortable quarters with good ventilation, but avoiding cold draughts.

CHAPTER XXVI

MUSCULAR MOVEMENT AND EXERCISE

What is needed for motion? Two things are needed, muscles and bones. When you raise your hand, a large muscle contracts or shortens, and this pulls the bones of the forearm upward. Figure 186 shows how the muscles are attached so as to bring this about. (You can easily make a model of this with two sticks and a piece of elastic band.) Something similar is found at each joint of the arms, hands, legs, and feet.

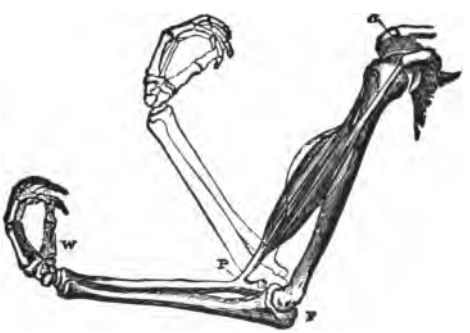

FIG. 186. — Action of biceps muscle of the arm.

What is bone? The bone is not a dead thing, but very much alive. If you break a bone, it soon grows together again. The hard part contains little living matter, but the marrow is full of it; it is in this marrow that the blood corpuscles are formed (page 364).

Burn a piece of bone; notice the beautiful structure, strong and light. This is mineral matter such as plants take up from the soil (page 57), and makes splendid plant food. Bone is widely used for fertilizing.

Place another piece of bone in acid (one part muriatic acid to six of water); this will dissolve away the mineral matter and leave the gristle. This is the part which was burned away in the first experiment.

What is muscle? If you look at a thick piece of steak taken from a leg of beef, you see that the meat or muscle is made up of separate strands. Each of these is made up of smaller strands, and these of still smaller. The smallest strands, made of fibers much finer than the finest hair, are called muscle fibers. Blood vessels go between the fibers to supply food and air (oxygen), so that food may be burned and force or energy set free to do work. Nerves also go to them to control the work by making them start and stop, or go faster or slower.

Some muscles are under the control of the will (voluntary muscles); the brain sends a message along nerves to the muscle and it contracts. Such are, for example, the muscles of the hand. But you cannot by willing it make your heart beat faster or slower; it is not under the control of the will; such muscles as those of the heart are called involuntary.

Heart action. The heart is the most important muscular organ of the body. It contracts on the aver-

age about seventy times every minute during our whole lifetime, and so it does far more work than all the other muscles together. If it stops working, death occurs almost at once. The heart is about as large as a closed fist, lying in the middle of the chest (not on the left side, as often stated), with the lungs on each side of it.

There are really two hearts, a right and a left, side by side, looking like one organ. Each of these acts like a syringe: the blood enters from above and is squeezed out below with considerable force into the arteries.

When a small artery or vein is cut, a blood clot (page 364) soon stops the bleeding. When a larger one is cut, we must stop it by tying a cord or handkerchief around the arm or limb and twisting it tightly with a pencil or piece of wood. If the blood comes in spurts (artery), we place the cord on the side *nearest* the heart; if it comes evenly (vein), on the side away from the heart. The wound should be disinfected (see page 254). There is much more danger of bleeding to death when an artery is cut; arteries are protected by being deep in the body, while veins are near the surface.

Effect of exercise. When a muscle begins to work (contract), it burns more food, and the temperature goes up; we soon become warm from exercise. At the same time waste substances are formed by the burning (carbon dioxide and poisonous substances), and if they cannot be taken away fast enough, the muscles get stiff and sore. They are in fact poisoned.

If we go right on with our exercise, this stiffness soon stops, because the body learns to remove the waste substances faster. This has a very good effect on the *health of the whole body.* Both heart and lungs help in this; the heart beats faster, sending more blood to the muscles and all over the body. We breathe faster and deeper, thus purifying the blood better.

At the same time the skin and kidneys begin to work harder in getting rid of waste substances. The more we exercise, the more we perspire. The perspiration of the skin is full of waste substances, and it not only takes them out of the body, but greatly cools the body by evaporation. The kidneys (whose appearance is familiar to all) are found in the back of the abdomen; they take waste substances out of the blood and discharge them as urine. If their purifying work stops, death occurs in a short time.

After vigorous exercise a cold shower-bath and rub are in order. This has several good effects.

First, the rubbing takes away the perspiration with its poisonous substances, cleans out the sweat pores, and puts them in good condition.

Second, it cools the body.

Third, it has a very soothing and pleasant effect on the nerves.

Fourth, it has a marked effect on the arteries under the skin. The tiny muscles which surround these arteries contract when chilled by the cold water, thus

keeping blood away from the skin, which grows pale, or even bluish, in prolonged cold. In a short time, however, they relax; more blood comes to the skin, making it glow and giving a fine sensation of warmth. Cold baths exercise the muscles which surround the arteries and keep them both in good condition, and this prevents us from catching cold when suddenly chilled (page 368). People who take a cold shower or sponge bath every morning are little liable to colds, and need only an occasional warm bath to keep the skin clean and in perfect condition. Hot baths relax these muscles, and so make the skin red; but their effect is to make one more liable to catch cold; they are therefore best taken before retiring.

Kinds of exercise. No one can keep well long without exercise. This should be taken regularly. The best exercise is that which exercises the most muscles in the open air and is not too violent. Since the leg muscles are the largest in the body, walking and running take first rank. But exercise of the waist muscles, as in rowing, chopping or sawing wood, or digging in the garden, has an especially good effect on the bowels (page 359).

Rest and repair. All exercise destroys muscle, and to replace it two things are needed: rest and food. Plenty of sleep, especially during the years of growth, is just as necessary as exercise. Abundance of good food, especially protein (page 348), is likewise needed.

To atheletes in training plenty of rare meat, coarse bread, eggs, vegetables, and fruits are given, so as to make muscle; pastry and fats are hardly given at all.

Care of animals. Animals need regular exercise. They should not be confined in close quarters if it can be helped. Too much and too violent exercise is very bad for them.

They should be kept as clean as possible. Pigs should have pens with plenty of water in which to bathe; they are naturally cleanly animals. Horses should not be shut up day after day without exercise, and they should be well groomed.

The food of an animal should be proportionate in quality and quantity to the amount of exercise it takes (page 348).

We have now learned something about how animals live and how they should be cared for. We may now study the different kinds of farm animals.

CHAPTER XXVII

FARM ANIMALS

No farm of any size can be run well without farm animals. Horses are needed for cultivation and hauling, as well as for the healthy exercise of riding. Oxen may be used for draft instead of horses, but they are slower; cattle are needed for meat and milk supply, whether for the house or for commercial purposes. Hogs are raised for meat, and serve for cleaning up after the larger stock, which usually waste a good deal of feed. Sheep are raised for their wool and for meat. Fowls of various sorts (chickens, turkeys, ducks, geese) are wanted for eggs, for meat, and also for their feathers. Pigeons are wanted mainly for their meat, especially the squabs or young pigeons.

For each of the different purposes served by these animals, special breeds have been developed by selection and breeding. The farmer raises one or more of these breeds according to the particular line of farming he intends to carry on. There are, of course, "general purpose" horses, cows, and sheep, which serve for convenience in small households or farms where only one

of a kind can be kept. But so soon as stock-growing on a larger scale is attempted, pure-bred animals for particular purposes are necessary. "Scrub stock," not adapted to any special purpose, does not pay so well as pure-bred or at least high-bred stock. Scrub animals do not give the best return for their feed; their work (as in making milk or meat) is poorly and expensively done. It is said that a Russian peasant can make a wagon with no tool but an axe. But it takes him a long time, and the wagon is poor and clumsy, and does poor work expensively; while a wagon properly made with good tools works quickly and cheaply. So do well-bred animals when compared with "scrubs."

Then again, well-bred stock is more gentle and intelligent than the "scrub" usually can be made to be even by kind treatment. Compare the kind, gentle face of a Jersey cow with that of a common one. With a high-bred horse (figure 187) the Arab master makes friends almost as with a human being, while the wild scrub horse of the Patagonian plains is as dangerous as a lion, and is very hard to tame.

Again, stock for different uses require different feeding. Starchy food will make fat, but no muscle or meat. To get these we must use feed rich in protein or gluten (see page 348). Work animals we feed so as to give them good, strong muscles, and some fat. Hogs we mostly feed for fat, but when we want large, fleshy

FIG. 187. — Arabian horse.

hams, we must use more protein in their food (see page 348).

And so the different feeds must be mixed so as to make what is called a "balanced ration" for each particular purpose. To do this rightly we must know something of what food substances are contained in the various crops and feeds (see page 354).

Horses. The horse as we see it to-day came from the Old World. The so-called wild horses of the Plains are simply descendants of horses that have escaped from stock ranches. Native American horses did however exist in former times; for we find the bones of several kinds of horses in rocks of western America (figure 188).

The extreme type of draft horses is represented by the heavy, thickset Percheron, Clydesdale, and Shire, much used by the draymen of cities. They are slow but steady in movement and can draw enormous loads.

The opposite extreme is the slender, graceful racehorse, light of body and with light, slender limbs. He is built for speed and quick motion, but is not fit for heavy draft. A somewhat similar type is the American trotter. Figure 189 shows these two types and one other.

Between the extremes we have numerous types of horses. Among them is the carriage horse, of which there are several special breeds, such as the English hackney and German coach horse and several others. Carriage horses are ex-

pected to be moderately fast in gait, and sufficiently heavy in build to pull a fairly heavy load.

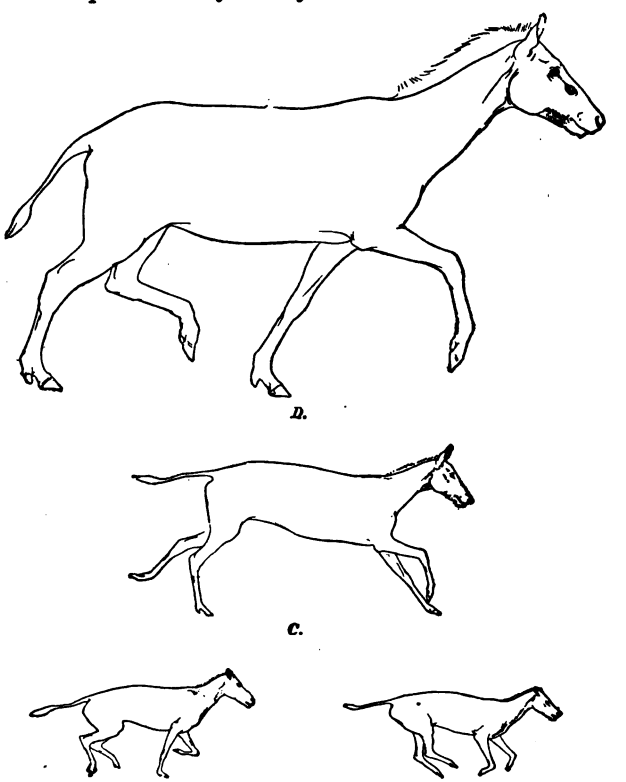

FIG. 188. — How the horse has increased in size. The smallest fossil horse (*A*) was no larger than a dog and had four toes on the front foot and three on the hind foot. (*D*) was 40 inches high with three toes on each foot. See *Century Magazine* for November, 1904.

Then there is the pony race of small horses, good-tempered and yet brisk in motion, but quite hardy and tough.

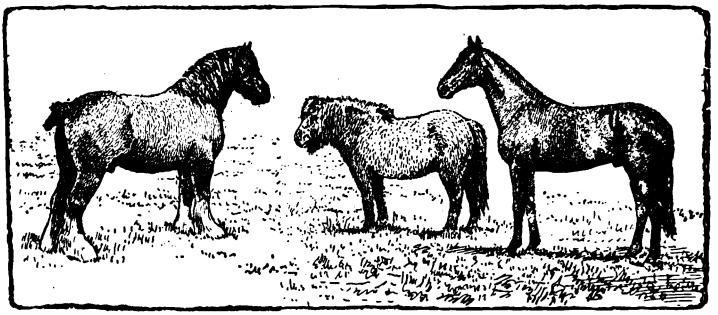

FIG. 189. — Different kinds of horses: draft horse (at the left), Shetland pony, trotter (at the right).

The Indian ponies of the northern tribes, and the small Shetland ponies from the islands north of Scotland are well known.

FIG. 190. — Bucking broncho.

Few animals respond as quickly and intelligently to kind treatment as does the horse, and so little deserve the ill treatment they so frequently undergo. The most "vicious" horses can be made gentle by kindness; even the "bucking broncho" (figure 190) can be thus subdued by a person having both patience and good will.

The ass, donkey, or burro, as it is commonly called in the West, is still found wild in Central Asia (figure 191), but has been domesticated from the earliest times. Though small in size, the ass can carry heavy loads

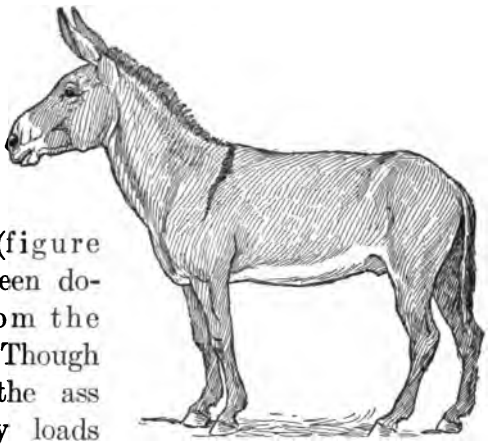

FIG. 191. — Wild ass.

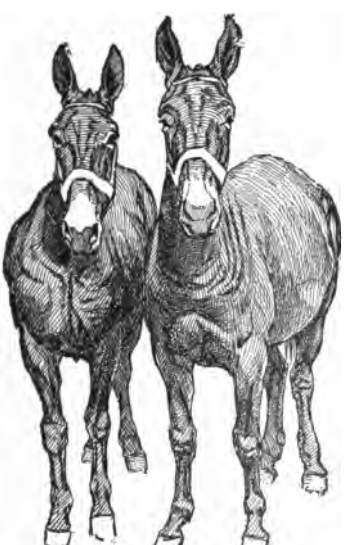

FIG. 192. — Mules.

long distances, and can live on feed that horses would scorn. The *mule* (figure 192), a hybrid between the horse and ass, has the hardiness of the ass and its long ears, and is much prized for hard steady work of all kinds. The mule is very intelligent, and is sure-footed on mountain roads where most horses would break their own and their riders' necks. But mules *will* kick.

Cattle. The wild ancestors of our common cow are still found in Russia, where they are protected by the government. They do not differ much from some tame breeds.

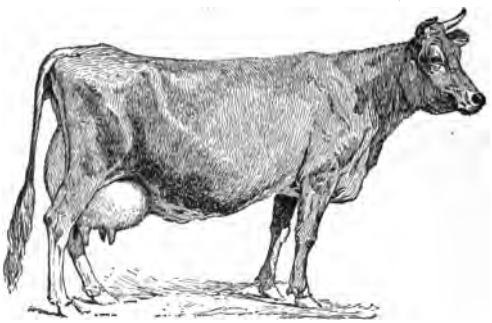

FIG. 193.—Milk type.

Of horned cattle there are very numerous breeds. There are two chief types; one for milk (figure 193), the other for beef (figure 194). The *milk breeds*, of which the Jersey and Guernsey are the extreme types, are slenderly built, especially in the fore part of the body, but have a very large milk bag. Their milk gives plenty of rich cream. The cows are very gentle.

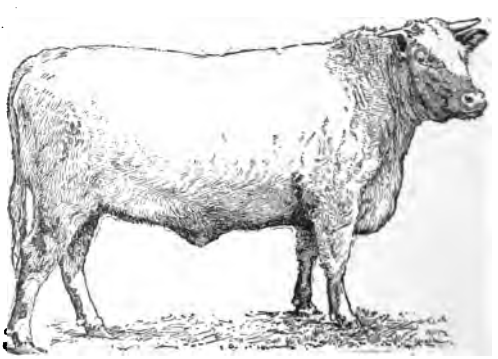

FIG. 194.— Beef type.

The beef breeds, of which the Shorthorn (Durham) is a type, have a thickset, stocky body, with plenty of flesh both behind and before. Some of these are

good milkers, both for quantity and quality. When they get old, they can be fattened for the butcher, while the best milking breeds are worth but little for meat. A Jersey cow in full milk is usually quite lean and shows the ribs, and even the Jersey calves are little valued for veal.

The cuts of beef are shown in figure 195.

Most well-bred cows have straight backs, while "scrub" cows usually have sagging backs.

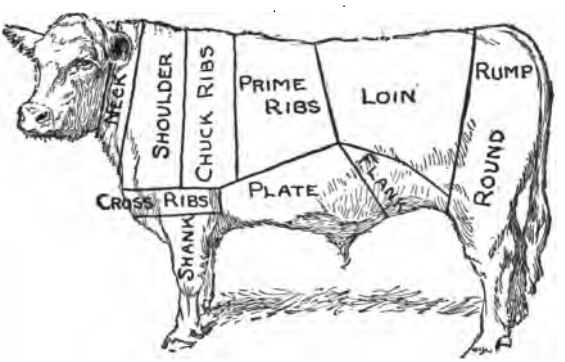

FIG. 195. — Cuts of beef.

We have a number of other breeds, such as the Ayrshire, the Holstein-Friesian, the Hereford, and others. While all those already mentioned, except the Ayrshire, have rather short horns, the Devon has long horns. The longest horns of all are borne by the Texas longhorn, once seen all over California, but now almost gone. It was noted for speed rather than milking or beef qualities, and was formidable in a rush or stampede (figure 196).

Large herds of cattle are pastured on the plains of the

Western United States, for the meat supply of the Eastern states and also of Europe. For the best grades of beef these cattle are fattened or "finished" in one of the corn-growing states (see page 278).

Nearly every country in the world has its special breeds of cattle, more or less adapted to local conditions. In the Philippine Islands, Malaysia, and Ceylon, they have the water buffalo or *carabao*, which needs several daily baths. In India the common cow is the white *zebu*, which is quite small and has a hump over the shoulder. In Tibet the long-tailed *yak*, which can live and work at heights over ten thousand feet, and up to twenty thousand, is alone used. It not only serves for riding and carrying loads, but also gives milk from which butter is made. In the United States an attempt is being made to domesticate the original wild buffalo or bison of the great plains. Once it existed in countless herds, but few are now left. Buffalo robes are very valuable for their thick, curly covering of hair.

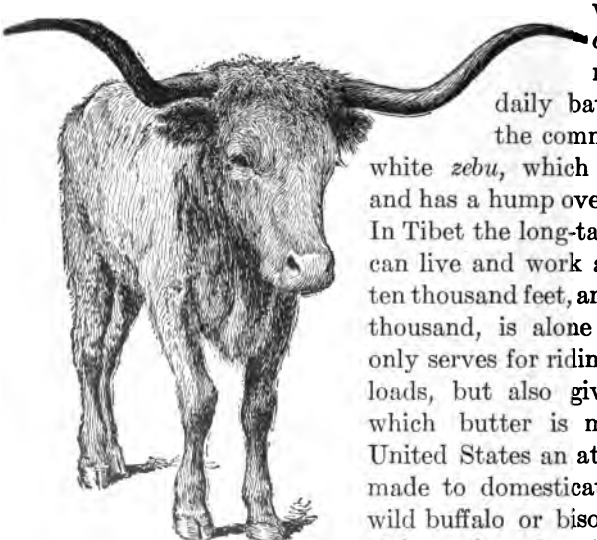

FIG. 196. — Texas longhorn.

Cattle are the chief source of skins from which leather is made by tanning with oak or other barks. The skins or hides of other animals can, of course, be made into leather also. Soft leathers for gloves are made from kid or sheepskin by rubbing with alum, salt, and yolk of egg.

Dairying means the production of milk and cream and the making of butter and cheese. In the United States the cow is the only animal used in dairying, while in some parts of Europe the goat is also important.

To make cows produce plenty of milk they must be of the right breed. They must get plenty of good food, be treated gently, and kept very clean and comfortable. Milking is still mostly done by hand, but many now use the milking machines, which milk several cows at a time and keep out the dirt, dust, and bad odors which easily get into the milk in hand milking. Milk takes up all kinds of odors very easily. When milk is kept warm, bacteria multiply very rapidly in it. Even if there were only a few bacteria when the milk was drawn from the cow, there may be hundreds of thousands after twenty-four hours. If among these there were disease germs, the milk becomes very dangerous, particularly to children.

The cows and the persons who milk them must be clean when the cows are milked. The milk should pass into the pail through a cloth stretched over the top. The milk should be drawn out of the pail (without taking away the cloth) by a tube (siphon) reaching to the bottom. It should then be cooled and placed in cans which have been well steamed (and not rinsed afterwards). In cities the milk should be delivered in closed bottles. Milk treated in this way will keep

FIG. 197.— A modern sanitary cow stable.

fresh for several days because there are so few bacteria (see page 261). Milk for babies in sometimes kept fresh by heating to 155° F. for twenty minutes, and then cooling it. This is called pasteurizing (see page 261).

When milk is left quiet, even for a short time, we find cream gathering on the top, because the butter-fat it contains is lighter than water. This cream we may after a while skim off for table use, or gather it till we have enough for a churning into butter and buttermilk. Or we may leave cream and all for a couple of days to sour, and make clabber. This is much liked by many people, and is a very healthful food, as also is buttermilk.

But in creameries, where hundreds and even thousands of gallons of milk must be handled every day, we cannot wait for the cream to rise. The milk is there run into the bowl of a machine called a separator. As this bowl is made to turn rapidly, we find the cream gathering in its middle, while skim milk goes to the outside. Two pipes are put in in such a way that the cream runs out of one, the skim milk out of the other, and so in a very short time large quantities of milk can be much more thoroughly skimmed than can be done by setting in pans. Then the cream is set aside to ripen for churning, while the skim milk is fed to pigs or made into a kind of cheese.

FIG. 198. — Separator.

Butter is now made from the ripened cream in large revolving churns instead of the old dasher churn, which gave a good deal of trouble. Pure milk should make from 4 to over 6 per cent of butter.

Cheese is made from the whole milk, or from milk partly creamed, by mixing in some rennet (made from the inside of calves' stomachs); this causes the milk to thicken (curdle) when it has been properly warmed. When the curd has come together, it is cut up with a wire frame, and then the whey is drained off. Then, after salting the curd to taste, it is put into ring-shaped molds into which cheese cloth has first been laid. This is then folded over, and the full molds placed on edge in a trough, in which a long screw carrying a press board ("follower") can be made to squeeze out the last of the whey. This makes the cheese into solid cakes. These are then taken out of the rings and put on shelves in a cool cheese room to cure. The curing takes several months.

Many different kinds of cheese can be made by varying the manner of making, as is done in different countries. The different flavors of cheeses are largely produced by the action of different kinds of bacteria while ripening, and we put these in purposely to produce such kinds as we want. Emmenthaler cheese, once made only in Switzerland, is now made in the United States also.

Goats. The goat, like the sheep, has been so long domesticated that its wild ancestor is uncertain, but it is most probably the wild goat of the mountains of Central Asia. The goat is found more or less all over the world, being even more easily satisfied as to its food than the sheep. Goats, like sheep, are very destructive to pastures when too many are put on. They

will browse on bushes and young trees and injure them, and hence they are sometimes used to clear new ground of brush or chaparral, of which they will eat almost any kind. Hence, they must, even more than sheep, be kept out of forests in which the reproduction of young trees is desired. In a garden a goat will do great damage in a short time.

FIG. 199. — An Angora prize winner (owned by C. P. Bailey & Sons).

Goats will climb mountains and rocks where neither sheep nor cows could go, and make a good living. They will leap or climb over low fences very easily. They are therefore most commonly seen in mountainous countries.

In some countries goats are kept chiefly for their milk, which is very rich but has a slight "goaty" flavor, which is also found in the cheese made from it. There are some strains of goats specially valuable for their milk. But the meat is dry and not very palatable, unless the animals have been especially well fed for that purpose.

There are however two varieties of goats that are highly valued for their hair. One of these is the Angora goat, so named from its place of origin in Asia Minor. It has long silky hair from which mohair fabrics are made. The other is the Cashmere goat, quite similar to the Angora, but prized chiefly for the fine, soft hair it produces underneath the long-haired outside coat. From this inner hair Cashmere shawls are woven in the valley of Cashmere and elsewhere in Northern India.

The best kid gloves are made from the skins of young goats, but much of what goes by that name is made from lambskins. Such skins are also used for fine shoes.

Sheep. Many kinds of wild sheep are found in temperate countries all around the world, but it is not certain from which of these our domestic breeds of sheep were derived. From the most ancient times, sheep have been prized for their fleece or wool, and for their flesh. As with other animals, different breeds have been developed to serve these two different purposes. The breed most prized for fine wool is the *merino*, first developed in Spain. The races most commonly esteemed for flesh are the Shropshire and the Southdown. They are so called from the downs (or coast flats) of southern England, whence they have spread over the

world. But as in the case of cattle, almost every sheep-raising country has its own breeds, adapted to its own conditions.

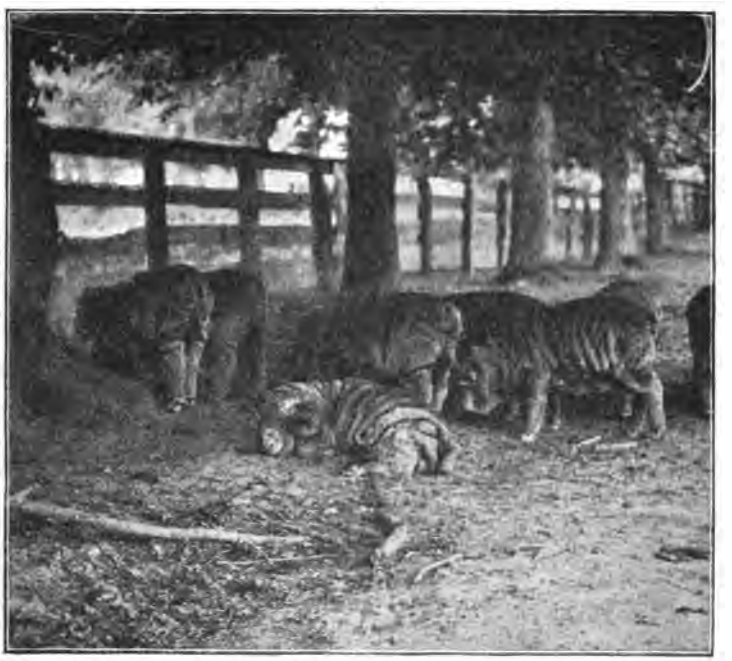

FIG. 200. — Merino sheep.

In general sheep will do well on much poorer food — mostly pasture — than beef cattle. They will therefore thrive on arid plains, and on desert vegetation where cows would starve. Of course, the finest wool and meat require good feed. But we find large flocks of sheep on the heather plains of Europe and Asia, and on the barren hill country of

Persia, just as we see them on similar ranges in our Plains country and in our mountains.

Sheep will eat rough, dry, prickly plants which only the burro and goat would touch. But the sheep bites deeply into the plants it crops and often destroys them, so that particular care must be taken not to put too many animals on

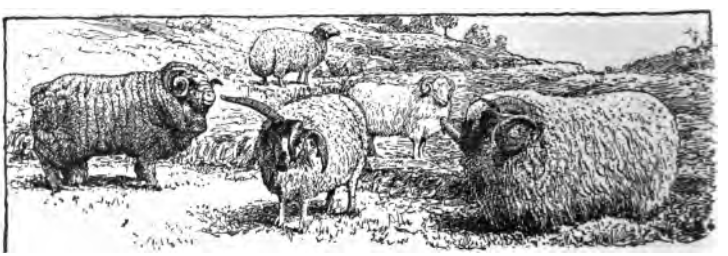

FIG. 201. — Different kinds of sheep: fine-woolled wrinkled merino (at the left), long-woolled black-face Highland (at the right.)

a pasture (overstocking), or keep them there too long; else only weeds will be there the next season. That is why the cattlemen so often object to sheep being driven over their pastures.

One of the important services sheep render to the farmer is to eat off the stubble of grain after harvest, leaving their droppings to return to the land. This is vastly better than to burn stubble or straw, when only the ashes are left.

The Hog, or Swine, seems to have been derived from the wild hog of Europe, where the wild breed still roams in the large forests and is hunted as game. Hogs will quickly become wild again when turned out into the woods, and then become a good deal like the "razor-

Fig. 202. — Sheep range in Utah.

back" hog in the picture (figure 203). They are then quite fierce and dangerous, for the tusks of a wild boar are nearly as bad as the horns of a mad bull.

FIG. 203. — Razorback.

The tame breeds, however, have become very gentle, especially those which become very fat and can hardly move any more. Such a hog is shown in figure 204.

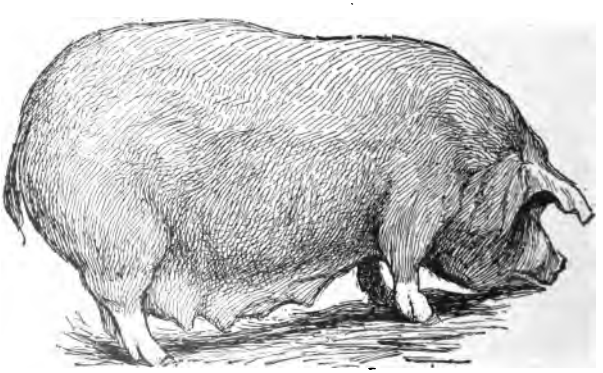

FIG. 204. — Lard hog.

The hog, while the least attractive of farm animals except when very young, is nevertheless one of the most important among them, particularly in the United States, where it serves to use the enormous crop of Indian corn or maize, of

which a large part could not be profitably used in other ways. The home consumption of pork in its various forms, of which hams, bacon sides, shoulders, and lard are the most important, is very large, and a very extensive export trade in the same articles is carried on; "corn-fed pork" being esteemed all over the world, on account of its firmness and flavor. The United States produces more hogs than any other country in the world. The manner in which hogs are cut up is shown in figure 205.

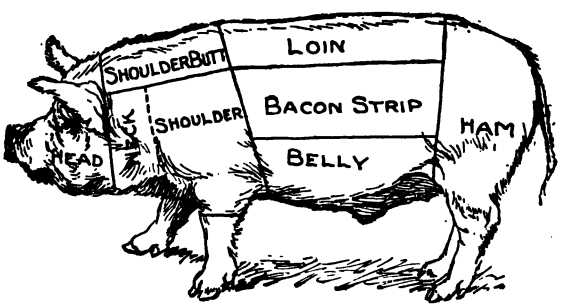

FIG. 205. — Cuts of pork.

Naturally, the raising of hogs on a large scale is carried on mostly in the "corn-belt" states (page 278). But a few hogs are found on nearly every farm, because they serve to make use of the offal of every kind. There are few eatable things which swine will not eat. Not the least important economy which hogs make possible is that they will eat the undigested corn from the droppings of cattle and horses, since these do not chew the kernels well. Much other waste, including skim milk from the separator (see page 389), can be most profitably consumed by pigs.

On much of the Pacific Slope, where little corn is grown and hogs are raised only for home consumption, they are

largely fed on alfalfa pasture, with refuse grain or other strong foods to "finish" them for the market and firm their flesh. The Berkshire and the Poland China are the ones most commonly used in such regions.

While swine are certainly not very shy of dirt, yet it is well to keep them as clean as possible. Pigsties should be properly littered and cleaned from time to time, for healthful and well-flavored meat and lard cannot be expected from badly kept pigs.

Trichina, a very minute parasitic worm, sometimes gets into the flesh of swine. When such flesh is eaten it is likely to be fatal to man. It is probably due to unclean sties and food or water. But the trichina also infests rats and mice, and hogs eating them will become infected. Pickling, salting, and smoking will not kill these parasites; this can only be done by thorough boiling or roasting. It is hardly ever safe to eat raw ham.

Chicago and Kansas City are the largest pork-packing centers, and next come Indianapolis and Cincinnati. In the large establishments, where tens of thousands of hogs are killed daily, every part of the animal is made useful. The hair, scraped off after scalding, is sorted into bristles for brushes of all kinds, and also for use in plastering walls. The entrails and other inside parts are made into fertilizers. Any grease is saved for soap making. The blood is dried and also makes a very valuable fertilizer. The lard tried out from the fat parts is not only used for cooking, but also for making lard-oil and candles.

CHAPTER XXVIII

FARM ANIMALS (Continued)

Dogs have been the companions of man from the most ancient times of which we have knowledge. They are shown in the carvings of ancient Egypt and Greece and other ancient peoples. Of all the domestic animals dogs have probably been developed into the greatest number of widely different forms and sizes. So that it is sometimes not easy to say exactly how we know such unlike animals as a bulldog and a King Charles spaniel both to be dogs; yet we all agree that they are such.

There are many kinds of wolves that so greatly resemble some dogs, that when tamed it is difficult to distinguish between them. Some gray collie dogs resemble the grey wolves (particularly the coyote) so much that they are liable to be shot as such by mistake. The slender greyhound seems to have its wild ancestor in the wolf of Tibet. The Eskimo sledge dogs are hard to distinguish from the wolves of the Arctic regions. Many large dogs are quite ready to turn back to the wolfish habit of killing sheep, in company with other dogs or even with wolves. In some of the Cotton States sheep

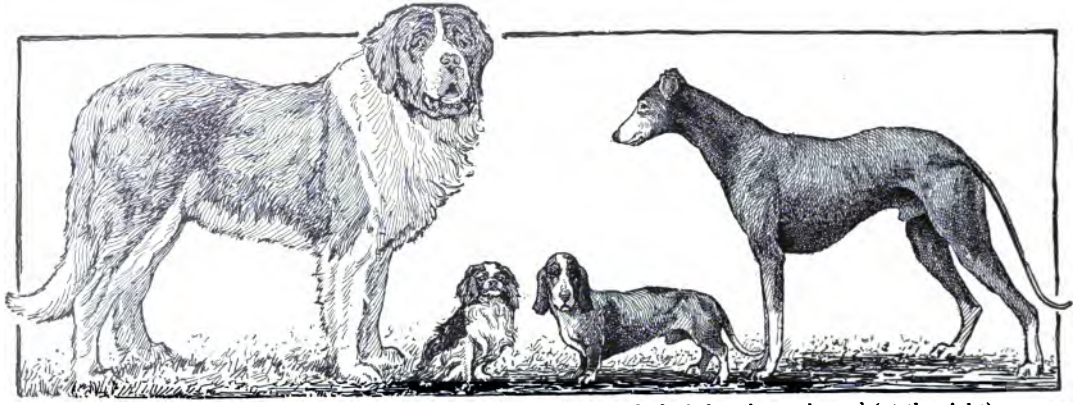

FIG. 206. — Kinds of dogs: St. Bernard (at the left), spaniel, dachshund, greyhound (at the right).

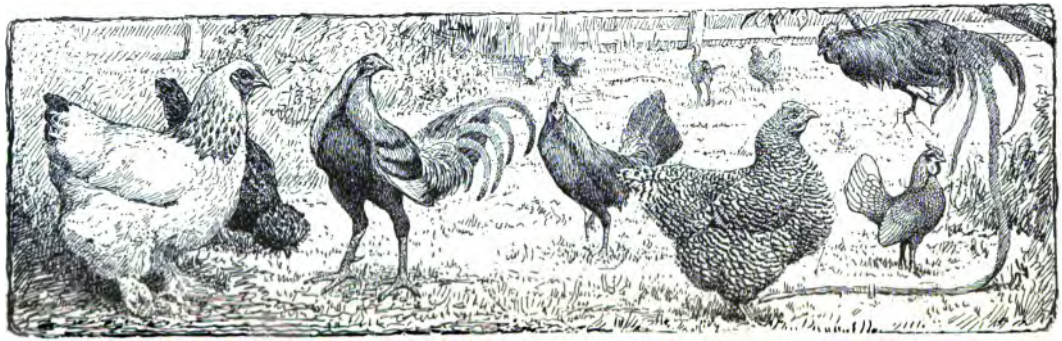

FIG. 207. — Kinds of fowl: light Brahma (at the left), bantam, long-tailed oriental fowl, jungle fowl, etc.

raising has been almost given up, because of the large number of dogs kept by negroes and poor white people. The affection of dogs for their masters is evidently the reason why people who have little happiness in their daily lives want at least to have the love of a dog.

The watchdog that guards the house, the collie that watches over, rounds up, and brings home the sheep, the Newfoundland dog that will rescue a person from the water without even being told, the St. Bernard dog that will discover travelers buried under the snow and carry them food and drink, the many small pet dogs that amuse children and "grown-ups" in the household, and the intelligent trick dogs of shows are known to all.

The cat has been domesticated so long that we do not know whence it came or what wild animal was its ancestor. The ancient Egyptians had a great veneration for cats, and we find vast numbers of them in the Egyptian tombs, embalmed and buried like human beings. Our common cats are much like these. But there are not as many varieties of cats as there are of dogs. The best known are the long-haired Angora, the slate-gray Persian cat, and the almost tailless Manx cat, from the Isle of Man, England.

The Angora cat is by far the gentlest of the entire cat tribe, which includes not only the common wild-cat or catamount, but also the lion, tiger, leopard, our mountain lion or puma, and many others. On the whole they are the most dangerous group of the wild animals.

We keep cats about our houses to kill and scare away rats and mice, but they are very useful in catching gophers, field mice, and other small pests. As household pets they are not altogether safe, for they will bite or scratch even on slight provocation. Cats easily become wild when they hunt birds, and on the seashore they will also catch crabs and other shellfish.

Domestic fowls. The most familiar is the common hen and cock (or rooster). The original home of the wild fowl was in southern China and Malaysia. It spread over the world in early days, as is shown by the mention of the cock crowing in the time of Christ. The "barnyard fowl" is met with in all countries where agriculture is practiced, and is valued both for eggs and meat.

As in the case of all domestic animals, breeds of chickens have been developed for special uses. We must add also a third, the fighting cock, which corresponds to the extreme type of the race horse, good only for sport. The small, slender fighting cock is most similar to the original wild fowl. But from eastern Asia we have also received the Brahma, Langshan, and Cochin fowls, the largest and most fleshy of all. They are grown mostly for their meat, and lay few but very large eggs. Since, however, eggs are sold by the dozen, and not by size or weight, we usually use smaller breeds for egg-laying, especially the Leghorn, called so from the city in Italy whence they first came. The Leghorns will not often sit long enough to hatch their own eggs. So we must get other hens, or incubators, to hatch them. Almost any common hen of mixed breed will do this, but not

all know equally well how to raise a brood of chicks. In the United States the Wyandotte and Plymouth Rock breeds are in high favor for the production of both eggs and meat, and they make good mother hens.

As hatching and raising a brood keeps a hen busy for six or seven weeks, artificial incubators and brooders are now used by all large poultrymen for hatching, and warmed "artificial mothers" for raising the chicks. When these are skilfully used and cared for, good healthy chickens are reared, and the hens can keep busy laying eggs in the meantime. In China this artificial hatching, in brick or mud ovens with shelves on the sides to hold the eggs, has been done from remote times.

Besides the useful breeds, we have among chickens the pretty, small bantam, as among horses we have the small Shetland pony. They are quick and lively and very intelligent, but serve only for ornament.

Poultry raising has become a very important industry in California, especially along the coast, where the even, mild climate is very favorable. But everywhere chickens should be divided up into small flocks or colonies of not over twenty-five or thirty, and given sufficient room for exercise and scratching. When many are kept together in small pens or houses, diseases are sure to come. To prevent these it is of first necessity to provide the poultry with clean water, and in feeding prevent their food from being mixed with their droppings. Also, give them a chance to dust to keep off mites, and to get some gravel to help grind their food, and lime to help make eggshells.

Turkeys. Despite their name, turkeys are natives of North America, where the wild bird can still be hunted in the woods.

Wild turkeys are taller and more slender than the tame kinds; they fly with great ease and roost on trees. When caught young they are readily tamed, but keep the habit of flying.

Turkeys are almost altogether raised for their flesh. The eggs are valuable for hatching, and are not sold for eating to any extent. Turkey hens are not very good sitters, and the eggs are now mostly hatched in incubators. Young turkeys are quite delicate, and half of them frequently die of various troubles, unless very carefully handled. Clean food and pure water must be supplied them even more carefully than to chickens.

The Bronze turkey is the best known improved breed, often reaching a weight of over thirty pounds. Its plumage is much like that of the wild bird. Other kinds are chiefly distinguished by their colors.

Ducks and geese. Unlike chickens and turkeys, various kinds of ducks and geese are found all over the temperate zone. Wild ducks and geese are still hunted in almost all countries. Their wide distribution and also their preservation is largely due to their migratory habits. The geese, especially, go northward to breed in summer, out of reach of hunters. The honking of the traveling flocks of wild geese is heard in spring and autumn all the way from the Atlantic to the Pacific coasts. Ducks usually do not travel as far as geese.

Our tame breeds of both geese and ducks are probably much mixed from the native breeds of different coun-

tries. Some are still thus distinguished, as the Pekin and Muscovy ducks, Egyptian goose, and so on.

Neither ducks nor geese are raised as generally as chickens. This is partly because they do best near ponds of water which cannot be found everywhere. Ducks, however, can do very well without such water, if plenty of good drinking water is supplied. Geese are most generally seen where there are at least wet meadows, and they need more space than ducks. In northern Germany they are herded on meadows like sheep, mostly by little girls. "Breast of goose" there takes the place of the Christmas turkey. In India geese are kept as swans are with us, and are considered very wise and beautiful.

While ducks, particularly the white Pekin, are frequently kept for egg laying, geese are raised almost entirely for their meat and feathers. The feathers are "plucked" in some countries as regularly as sheep are sheared for wool, and our soft feather pillows are filled with the down of geese. Goose quills from the wings were used for making writing pens until steel pens were invented.

Pigeons. There are about 500 different kinds of wild pigeons, and it is not at all certain from which of these kinds our domestic pigeons came, especially as there are so many varieties of these, such as the pouter, the fantail, and others. Our common pigeons probably came from the rock pigeon of Europe. Of the wild pigeons of the United States the dove (called from its plaintive song the mourning dove) and the passenger pigeon are the most generally known. The last-named once passed in countless numbers over the Eastern and

Middle States, and flocked together in "pigeon roosts" sometimes extending over miles of country. It has now become very rare from hunting, like the great herds of buffalo or bison that formerly ranged the great plains of the West.

A flock of pigeons will largely take care of itself, if left free to roam, invading neighboring gardens, fields, and barnyards. But they will always "come home to roost" unless driven out. As they make only very rude nests of a few sticks in which two eggs are laid, they are easily pleased. Pigeon houses, or "lofts" as they are called, soon become rather foul from the droppings of the birds. If it is desired to produce squabs (young pigeons) for the meat market, the nest boxes should be kept clean. It is best for this purpose to keep the flocks in large wire net houses with the nests all around, so that they can fly about and get plenty of air. Usually no special breeds are selected for this purpose.

Pigeons are able to make very rapid and long flights, and hence are sometimes used as "carrier pigeons" to take messages quickly to long distances. A "homing pigeon" will find its way back for hundreds of miles. A special breed of stocky, strong-built form is bred for this purpose; but others are similarly trained to long flights.

The honeybee. The honeybee is the smallest of the domestic animals cared for by man. Yet it is not the least important, and in California especially, bee keeping is a large industry. California makes more honey than any other state.

A large number of insects belonging to the bee tribe are found native in California, but our honeybee has

come from the Old World, and has been well able to take care of itself. "Bee trees" containing wild honey are found all over the United States, their hollows having been filled with honeycomb by swarms escaped from hives kept on farms or bee ranches. In California they have often taken possession of courthouse and other cupolas, from which the honey finally ran down into the offices. It has sometimes been very difficult to get rid of them, as a very small hole is enough to let them in and out. They also build in caves in rocky banks, from which the honeycombs have to be mined.

Bees visit all kinds of flowers to get honey from the honey glands inside the petals, as well as pollen for feeding the young bees, which they gather in bunches on their hairy legs. They also scrape off the sticky covering of buckeye, cottonwood, and other buds for use as glue to fasten the honeycombs.

They will also take any sweets they can find, such as the honeydew secreted by plant lice, and sweet fruit juices of all kinds. But it is a mistake to suppose that they ever wound a fruit in order to suck the juice, for honeybees have no jaws with which to break the skin even of an apple. They only suck the wounds already made by some biting insect or bird, and then enlarge them. They are of great use to the orchardist in the carrying of pollen to blooming trees that otherwise would set no fruit (page 93).

All this work is done by the worker bees. These are

females which lay no eggs. Egg-laying is the exclusive business of the one queen bee of each hive, and she may lay as many as 3000 eggs in one day, and she may live for five years. When she dies or gets too old, the workers make another queen from an egg that ordinarily would hatch into a worker, by specially feeding it in an enlarged cell. They also do this when the bees of one hive become too many for it, and then, when the new queen is fully grown, she leaves the old hive with a swarm of workers, which always cluster around the queen, and must then be caught and settled in a new hive. One hive or stand may have from 15,000 to 40,000 bees.

FIG. 208. — Queen, worker, and drone.

The male bee is called a drone. It has no sting and has to be fed by the workers. It makes a loud buzzing noise in flying, and when there get to be too many drones in the hive, the workers carry them out and sting or worry them to death, as being of no use. (See page 200.) Read what is said about bees in Kellogg's "Insect Stories."

The wax from which the honeycomb is made is produced from honey by the bee itself, and comes out as wax scales

on the abdomen. To save the bees labor and honey, artificial comb foundations made of wax sheets are often supplied to the bee stands, which are best filled inside with frames that can easily be taken out when filled with comb and honey by the bees.

The worker bee works so hard flying back and forth (sometimes to long distances), building combs, and buzzing to ventilate the hive, that its life is shortened. Probably it does not live more than five months, and during the season of hardest work, sometimes only four weeks. So young broods must constantly be brought up to supply their places. The workers place food in the cells in which the queen has laid her eggs, and then seal them on top with wax. When the young grub has eaten all the food provided, it spins a cocoon, and after twenty-one days is ready to come out as a flying bee.

FIG. 209. — Beehive.

Bees are guided to where flowers grow much more by the perfume than by the color, and will go miles to find them if necessary. In California the wild blue and white sage and alfalfa fields, and in more northern countries red and white clover, are favorite pastures, as are orchard trees of all kinds when in bloom. The amount of honey a bee can carry in its honey sack is quite small, being about the size of an apple seed. So it takes very many such loads, and an equal number of

trips, to fill a single cell with honey, and hence bees are very busy.

As with all domestic animals, there are a number of improved breeds of bees. These are larger and produce more honey, and are easier to handle than the common black bee, which is quickly irritated, and is then quite savage. Italian and Carniolan bees are among the best, and can be sent by mail in little ventilated boxes. Such a queen introduced into a hive will soon transform it very nearly to its own kind. It is very instructive and not at all dangerous to have a hive of such bees at a school or home for study (see page 201).

APPENDIX

SPRAYS AND WASHES

WATER alone, applied with some force, will dislodge a good many insects, but most pests require the addition of some more active substance to the wash. The formulas below give the amounts necessary to make an oil-can-ful (5 gallons), and also a barrelful (40 gallons) of each mixture. Spray with heavy pressure for scale insects, and make everything thoroughly wet; but for other pests less pressure and material is necessary, for the leaves should scarcely be made to drip.

FOR INSECTS THAT EAT THE LEAVES AND FRUIT

USE A POISON SPRAYED ON THE FOLIAGE TO KILL THE INSECTS WHEN THEY EAT IT

NAME OF WASH	INGREDIENTS	FOR 5 GALS.	FOR 40 GALS.	DIRECTIONS
Lead Arsenate	Lead Arsenate	4 ounces	2 pounds	

FOR SCALE AND OTHER SUCKING INSECTS

USE MIXTURES WHICH KILL BY COMING IN CONTACT WITH THE BODY OF THE INSECT WHILE THE PLANTS ARE BEING SPRAYED

Kerosene Emulsion	Kerosene Sour Milk or Soap	3 pints 1½ pints 1½ ounces	3 gallons 1½ gallons ¾ pound	Mix hot by pumping through a spray-pump for fifteen minutes, then dilute. Use either sour milk or soap solution. One half as strong will do for plant lice. Twice as strong is safe when the leaves are off. An emulsion is more easily made if about twelve times as much soap is used.
Rosin Soap	Rosin Caustic Soda Fish Oil	1 pound ¼ pound 2 ounces	8 pounds 2 pounds 1 pint	Boil two hours with a small quantity of water, then dilute with warm water. It may be used one half stronger when the leaves are off. It is cheaper than the emulsion.

FOR SCALE INSECTS, FUNGI, AND MOSS

USE MIXTURES APPLIED IN WINTER WHICH CORRODE THE DEAD BARK, AND SO SOFTEN IT AS WELL AS KILL INSECTS BY CONTACT

Lime and Sulphur	Lime Sulphur	3 pounds 1½ pounds	24 pounds 12 pounds	Boil two hours with a small quantity of water, then dilute. This is for winter use only. If a third less of the ingredients is used, it will not injure foliage.
Sulphid of Potash	Caustic Soda Potash Sulphur Whale-Oil Soap	¾ ounce ¾ ounce 2¼ ounces 1 pound	6 ounces 6 ounces 18 ounces 8 pounds	Add the dissolved whale-oil soap after boiling the rest one hour; then boil all one half hour and dilute. This is for winter use only. If the whale-oil soap is omitted and one fourth as much of the other ingredients used, it will not injure foliage.

FOR FUNGI

USE MIXTURES THAT WILL PREVENT THE GERMINATION OF THE SPORES ON THE LEAF

Bordeaux Mixture	Bluestone Lime	½ pound ½ pound	4 pounds 4 pounds	Dissolve the bluestone and slake the lime separately. Mix when cool. The amount of lime may be increased if desired. When the leaves are off the trees, the mixture may be used two or three times as strong.
Ammonia Copper-Carbonate	Ammonia Copper Carbonate Bluestone Salsoda	5 ounces ½ ounce ¾ ounce 1 ounce	2½ pints ¼ pound 6 ounces ½ pound	If the bluestone and salsoda are used, dissolve them separately in a small quantity of water and mix when cool. The copper carbonate thus produced is then dissolved in ammonia. Do not dilute with water till it is all dissolved. It is not as good as Bordeaux mixture, but does not discolor the leaves.

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